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Engineering Library

JUL 16 1923

ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

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VOL. CXVI.—No. 3001.] *LONDON: FRIDAY, JULY 6, 1923.* [*Registered at the General Post Office, as a Newspaper.*] [PRICE ... 1s. BY FOREIGN POST 1s. 4d.

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1108

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ON ADMIRALTY AND WAR OFFICE LISTS.
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See Advertisement, pages 24 and 25, last week.
PATENT WATER-TUBE BOILERS, AUTOMATIC FEED REGULATORS,
And Auxiliary Machinery as supplied to the Admiralty. 2179

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The Strongest Chain in the World.
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Specification and Workmanship equal to Main Line Locomotives.
R. & W. HAWTHORN, LESLIE & CO., LTD., ENGINEERS, NEWCASTLE-ON-TYNE. 1133

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HIGH-CLASS ENGINES FOR ALL PURPOSES, also WINDING, HAULING, AIR COMPRESSING and PUMPING ENGINES. 1896
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Duckham's Patent Suspended
WEIGHING MACHINES—EAST FERRY ROAD ENGINEERING WORKS COMPANY, LTD. LONDON, E.—Hydraulic Cranes, Grain Elevators, &c.
See Illus. Advt. last week, page 15. 991

CRANES. All Types.
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Weldless Steel Tubes
for Water-tube Boilers, Superheaters, Shafting, Hydraulic Work, Boring Rods, &c.
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for Engine Works and Boiler Shops.
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Cochran MULTITUBULAR AND CROSS-TUBE TYPES **Boilers.**
See page 17, June 29. 1134

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—Practical Course of Instruction by Correspondence.—Address, for particulars and terms, 1463, Offices of ENGINEERING.

P. & W. MacLellan, Ltd.,
CLUTHA WORKS, GLASGOW.
MANUFACTURERS OF RAILWAY CARRIAGES AND WAGONS OF EVERY DESCRIPTION.
RAILWAY IRONWORK, BRIDGES, ROOFING, &c.
Chief Offices: 129, Trongate, Glasgow. Od 3547
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See's Patent Hydro-Pneumatic **Ash Ejector.**
Great saving of labour. No noise. No dust. No dirt. Ashes discharged 20 ft. clear of vessel.—Apply F. J. TREWENT & PROCTOR, LTD., Naval Architects and Surveyors, 43, Billiter Bldgs., Billiter St., London, E.C. Od 4535

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Tubes and Fittings.
Sole Licensees in Great Britain for the manufacture of "Armco" Rust and Corrosion Resisting Iron Tubes. 817
The Scottish Tube Co., Ltd.,
HEAD OFFICE: 34, Robertson Street, Glasgow.
See Advertisement page 73.

Royles Limited,
ENGINEERS, IRLAM, MANCHESTER.
FEED WATER HEATERS, CALORIFIERS, EVAPORATORS, CONDENSERS, AIR HEATERS, STEAM and GAS KETTLES, Merrill's Patent TWIN STRAINERS for Pump Suctions, } How's PATENTS.
SYPHONIA STEAM TRAPS, REDUCING VALVES
High-class GUNMETAL STEAM FITTINGS.
WATER SOFTENING and FILTERING. 5723

IRON & STEEL
Tubes AND Fittings AND Steel Plates.
STEWARTS AND LLOYDS, Ltd.
GLASGOW - BIRMINGHAM - LONDON.
See Advertisement, page 7. 1111

Drag Line Excavator.
Has moved 2,000 cube yards in one day. May be seen at Frodsham, near Chester. Reach 77 ft.; lift four to five tons; speed of working, one to three cuts a minute.
HARRY FAIRCLOUGH, Contractor.
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E. J. Davis, M.I.Mech.E., Gas Engines Inspected, Tested and Reported upon. Over 25 years' experience. Tel.: 736 and 737 Stratford. Wire: "Rapidising, London."—Great Eastern Road, Stratford, E.15. 1794

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Makers of WHEELS and AXLES, RAILWAY PLANT, FORGINGS, SMITH WORK, IRON & BRASS CASTINGS. PRESSED STEEL WORK OF ALL KINDS.
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Andrews & Beaumont,
CHARTERED PATENT AGENTS, 1902
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CARELS DIESEL & STEAM ENGINES (LONDON), LTD., Carlton House, Regent Street, London, S.W. 1. Telephone: Regent 3434.

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Boilers, Tanks & Mooring Buoys
STILLS, PETROL TANKS, AIR RECEIVERS, STEEL CHIMNEYS, RIVETTED STEAM and VENTILATING PIPES, HOPPERS, SPECIAL WORK, REPAIRS OF ALL KINDS.

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Head, Wrightson & Co., LIMITED.
See Advertisement page 37, June 29. 2402

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THOMAS HUNT & SONS,
Albion Ironworks,
Bridge Road West, Battersea, S.W. 11.
Est. 1854. 1484

Matthew Paul & Co., Ltd. Dumbarton.
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See Full Page Advt., page 80, June 22.

Taylor & Challen Presses
For Production of SHEET METAL WORK, COINAGE, CARTRIDGES AND GUNPOWDER.
Foundry, Works, and Showrooms: BIRMINGHAM.
See advert., page 87, June 22. 3196

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FELLOWS BROS., LTD., 9158
BRADLEY HEATH, STAFFS.

Railway Switches and Crossings.
T. SUMMERSON & SONS, LIMITED,
DARLINGTON. 1319

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and Principal Provincial Cities and Abroad.

Aluminium in Rolling-stock Reduces Weight Power and Maintenance Costs.
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For the prevention of Steam Boiler Explosions and for the attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.

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Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 1311

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of the

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY.

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Royal School of Mines.
City and Guilds (Engineering) College.

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EMPLOYERS REQUIRING MEN who have received a thorough training in the principles of Engineering, and who have obtained the Diploma of the City and Guilds (Engineering) College are asked to make use of the services of the Board. No fees.

These men have received instruction (including practical work in the extensive and well equipped laboratories of the College) in Civil, Mechanical, and Electrical Engineering, including Mathematics, Physics and Chemistry. Their training has been such that they are capable of specialising in any branch of Engineering that may be offered.

A 967

Mining Engineering Exhibition.

THE SOUTH WALES INSTITUTE OF ENGINEERS.

In the DRILL HALL (Dumfries Place), CARDIFF, From NOVEMBER 20, to DECEMBER 8, 1923 (both dates inclusive).

Open from Two p.m. to Eight p.m., each day.

The Council of the SOUTH WALES INSTITUTE OF ENGINEERS INVITES APPLICATIONS for SPACE in the above exhibition. The last date for receiving applications is AUGUST 31, 1923.

The Drill Hall has been booked from NOVEMBER 21, to DECEMBER 14, 1923, so as to allow Exhibitors sufficient time for the erection and dismantling of Exhibits.

The Exhibition will comprise the following Exhibits:—

SCHEDULE OF EXHIBITS.

Section 1.

Scientific, Measuring and Recording Instruments as applied to all branches of Engineering.

Section 2.—Steam.

Water Softening and Cooling Plant. Boilers and Equipment. Pipes, Valves, Separators, etc. Drawings or Models of Modern Engines. Governors and Safety Devices, etc.

Section 3.—Electrical.

Motors of various kinds and Models of Winders. Switchgear, Cables, Controllers, etc. Electrical Tools and other Appliances. Overhead Lines. Small Motors. Electric Cranes. Telephones and Wireless Apparatus, etc., etc.

Section 4.—Mechanical.

Mechanical transmission of power above and below ground, and plant and equipment connected therewith. Bearings, Clutches, Ropes, Belts, Gearing, etc. Air Compressing Plant.

Section 5.—Workshop Appliances.

Machine Tools (Small). Pneumatic Tools. Hydraulic Tools, etc., etc.

Section 6.—General.

Shaft Signalling. Devices to prevent overwinding. Models of Pit-Cages, Tram Tipplers and Decking Devices. Models of Coke-Ovens, By-Product and Recovery Plant. Coal-Cutting and Conveying Machines. Models of Screening, Coal Washing and Sorting and Stone-Dusting Plant. Pumping Plant. Couplings, etc., etc.

Exhibits shall be as far as practicable arranged under their various Sections, but Exhibitors will be allowed when exhibiting under more than one Section, to group their exhibits on one Stand.

Forms of Application for Space, Ground Plan, etc., will be forwarded on application to MARTIN PRICE, Secretary, The South Wales Institute of Engineers, Institute Buildings, Park Place, Cardiff.

A 996

University of Liverpool.

FACULTY OF ENGINEERING.

Dean: Professor T. R. ABELL, O.B.E., M.Eng., R.C.N.C., Ret., M.Inst.N.A.

PROFESSORS AND LECTURERS.

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Harrison Professor—W. H. Watkinson, M.Eng., M.Inst.C.E., M.I.Mech.E., M.I.E.E.
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John William Hughes Professor of Engineering (Strength of Materials)—W. Mason, D.Sc., A.M.Inst.C.E., A.M.I.Mech.E.

MARINE ENGINEERING.
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Lecturer in Electrical Machinery—F. J. Teago, M.Sc., M.I.E.E.
Lecturer in Municipal Electrical Engineering—Vacant.

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Lecturer in Municipal Engineering—Associate Professor J. A. Brodie, M.Eng., Past Pres. Inst.C.E., M.I.Mech.E.
Lecturer in Dock and Harbour Engineering—Associate Professor T. R. Wilton, M.A., M.Inst.C.E., M.Cons.E.

NAVAL ARCHITECTURE.
Alexander Elder Professor—T. B. Abell, O.B.E., M.Eng., R.C.N.C., Ret., M.Inst.N.A.

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GEOLOGY.
George Herdman Professor—P. G. H. Boswell, O.B.E., D.Sc., M.Inst.M.M., F.G.S.

The Prospectus of the Faculty may be obtained on application to the undersigned,

EDWARD CAREY, Registrar.

A 57

Correspondence Courses for

Inst. Civil Engrs., Inst. Mech. E., London Univ. (Matric., Inter., B.Sc.), and All ENGINEERING EXAMINATIONS personally conducted by Mr. TREVOR W. PHILLIPS, B.Sc. (Honours), Assoc. M.Inst.C.E., M.R.S.I., F.R.S.A., &c. Also Day Tuition in Office. Excellent results at all Exams. Courses may commence at any time, and all Students receive individual tuition.—For full particulars apply to 8/11, TRAFFORD CHAMBERS, 58, SOUTH JOHN STREET, LIVERPOOL. 1295

Engineering Salesmanship

and SALES MANAGEMENT.—Write for brochure describing our special Course of training for posts of unlimited scope in this lucrative field.—DIRECTOR, Institute of Engineering Salesmanship, 333, Oxford Road, Manchester. 1401

TENDERS.

BENGAL-NAGPUR RAILWAY COMPANY, LIMITED.

The Directors are prepared to receive

Tenders for Two 10 Ton STEAM TRAVELLING CRANES.

Specification and Form of Tender can be obtained at the Company's Offices, 132, Gresham House, Old Broad Street, London, E.C. 2, on and after 29th June, 1923.

A fee of £1 1s. will be charged for the specification, which is not returnable.

Tenders must be submitted not later than Noon on FRIDAY, 13th July, 1923.

The Directors do not bind themselves to accept the lowest or any Tender.

By Order of the Board,
R. C. VOLKERS,
Secretary.

A 986

METROPOLITAN ASYLUMS BOARD.

Tenders are Invited for the

PURCHASE of ONE only, SECOND-HAND 5-ton FODEN WAGON and TRAILER, together with Fittings. Makers' No. 3178, built 1913, approximately 25 horse-power. The wagon and trailer may be seen at the Brook Hospital, Shooters Hill, Woolwich, S.E.

Forms of Tender, upon which alone offers will be considered, may be obtained from the undersigned.

Tenders, addressed as printed on the form, must be delivered at the office of the Board, Victoria Embankment, E.C.4., not later than Two p.m., 18th July, 1923.

By Order,
G. A. POWELL,
Clerk to the Board.

B 9

COUNTY BOROUGH OF CROYDON.

CENTRAL BATHS, CROYDON.

TO BOILERMAKERS AND ENGINEERS.

NOTICE IS HEREBY GIVEN that the Council are prepared to receive

Tenders for the Supply,

DELIVERY and FIXING of TWO CORNISH HOT WATER BOILERS, in the existing Boiler House at the Central Baths, Scarbrook Road, Croydon. Conditions of Contract, Specification, and Form of Tender may be obtained from the Borough Engineer, Town Hall, Croydon, upon deposit of One Guinea, which will be returned upon receipt of a *bona fide* Tender.

Tenders on the prescribed form to be sent to me not later than Eleven a.m. on Tuesday, 10th July, 1923, endorsed "Tender for Cornish Boilers, Central Baths."

Tenders will only be received subject to the Draft Contract, General and Special Conditions deposited at my office and which may be inspected during office hours.

The Council will not be bound to accept the lowest or any Tender.

JOHN M. NEWNHAM,
Town Clerk.

Town Hall,
Croydon,
27th June, 1923.

A 970

LIVERPOOL CORPORATION WATER WORKS.

CONTRACT FOR VALVES FOR OSWESTRY NEW FILTER BEDS AND STOCK.

The WATER COMMITTEE of the LIVERPOOL CORPORATION are prepared to receive

Tenders from Manufacturers

for the SUPPLY of certain SLUICE and other VALVES from 2 inches to 24 inches internal diameter inclusive.

The Plans may be inspected and copies of the Specification and Form of Tender obtained on and after Wednesday, 4th July, 1923, at the Water Engineer's Office, Alexandra Buildings, 55, Dale Street, Liverpool, upon payment of the sum of Two Guineas, which amount will be refunded upon receipt of a *bona fide* Tender and the return of the documents issued.

Tenders, endorsed "Tender for Valves," are to be sent through the post in a sealed envelope, addressed "Chairman of the Water Committee, Town Clerk's Office, Municipal Buildings, Liverpool," so as to be delivered not later than Twelve o'clock Noon, on Tuesday, the 24th July, 1923.

The Water Committee do not bind themselves to accept the lowest or any other Tender.

WALTER MOON,
Town Clerk.

Municipal Buildings,
Liverpool,
30th June, 1923.

A 981

Gas-Engine-driven Dynamo

FOR SALE, 60 B.H.P. Horizontal Premier GAS ENGINE, coupled to a 30 kw. Direct-current Bruce Peebles Dynamo, 220/230 volts, shunt wound, first class running order; also SECTION MAIN SWITCHBOARD; owners changing to public supply. Plant can be seen by appointment, Cheadle Royal, Cheadle, Cheshire.—Further particulars and Tender Forms from Mr. C. H. WORDINGHAM, M.Inst.C.E., Consulting Engineer, 33, Brazennose Street, Manchester. A 985

WIGAN UNION.

The Guardians of the Poor of the Wigan Union invite

Tenders for the Supply,

DELIVERY and ERECTION of ONE ELECTRICAL VERTICAL PUMPING PLANT, Heating and Domestic Hot Water Supply Apparatus, Alterations of Buildings, Additions, and making a Well, at the Poor Law Infirmary, Billinge, near Wigan.

Copies of Specification and General Conditions may be obtained from me, the undersigned, on payment of a fee of £3 3s., which will be returned upon receipt of a *bona fide* Tender, and Plans can be inspected at this office at any time during office hours.

Tenders to be sealed, and endorsed "Tender for Plant, Billinge Infirmary," to be delivered to me not later than Ten a.m. on Thursday, the 9th August, 1923.

The Guardians do not bind themselves to accept the lowest or any Tender.

By Order of the Board,
H. GORDON ACKERLEY,
Clerk.

Victoria Buildings,
King Street, Wigan.
2nd July, 1923.

B 11

LONDON & NORTH EASTERN RAILWAY COMPANY.

The Directors are prepared to receive

Tenders for Construction of

the TIMBERWORK required for the COMPLETION of the NEW NORTH SIDE STAITHS at Blyth.

Plans and Specifications may be seen, and Detailed Quantities and Form of Tender obtained, on personal application at the Branch Office of Mr. C. F. BURROUGH, the Company's Chief Engineer for the North-Eastern Area, at Forth Banks, Newcastle-on-Tyne, on and after July 2nd.

Sealed Tenders, marked "Tender for New North Side Staiths, Blyth," must be sent to the Joint Secretaries, at Marylebone Station, London, N.W.1, not later than Nine a.m., on Monday, July 23rd.

The Directors do not bind themselves to accept the lowest or any Tender.

JAMES McLAREN,
G. F. THURSTON,
Joint Secretaries.

Marylebone Station,
3rd July, 1923.

B 7

STATE ELECTRICITY COMMISSION OF VICTORIA.

TENDERS FOR PLANT.

Tenders are Hereby

Invited for the SUPPLY of the following MATERIAL for the Morwell Power Scheme.

Copies of Tender Form and Specification, etc., will be available for inspection and purchase upon application to:—

THE AGENT GENERAL FOR VICTORIA,
Melbourne Place, Strand,
London, W.C.2.

SPECIFICATION No. 23/93—TRANSFORMERS.

CHARGE:—10s. for two copies of Tender Form, Specification, Contract, Conditions, etc., complete. This charge will be returned on receipt of a *bona fide* Tender.

A third or any further copies will be supplied for the sum of 5s. each, but this charge is not returnable.

PRELIMINARY DEPOSIT:—A preliminary deposit of £50 is required to be lodged with each Tender.

The Commission does not bind itself to accept the lowest or any Tender.

Tenders on prescribed forms, properly addressed and endorsed, must be delivered to the undersigned in Melbourne, not later than noon, 25th August, 1923.

R. LIDDELOW.
Secretary,
State Electricity Commission of Victoria,
Melbourne, Victoria,
Australia.

A 869

ABERDEEN CORPORATION WATER WORKS.

EXTENSIONS 1920.

CONTRACT No. 13—NEW AQUEDUCT.

The Town Council of Aberdeen are prepared to receive

Tenders from Competent

Persons willing to enter into a Contract for the TRANSPORTING, LAYING and JOINTING of about 3 miles of 40-inch PIPING and ANCILLARY WORKS between BANCHORY and CRATHES.

The Drawings may be inspected and Specification, Schedule of Quantities and Form of Tender obtained, on and after 12th July, 1923, on application at the Water Engineer's Office, 41½, Union Street, Aberdeen. Early application is desirable, and no specification will be given out after 20th July.

For each Specification a deposit of Five Pounds sterling will be required, which sum will, after a Tender has been accepted, be returned to the Tenderer, provided that he shall have sent in a *bona fide* tender, based on the drawings, specification and schedule of quantities provided, with the schedule of quantities fully priced out in detail, and shall not have withdrawn the same.

Tenders, on the Forms prescribed, and enclosed in securely sealed envelopes, endorsed "Tender for Aqueduct Pipelaying" are to be addressed to the undersigned. No Tender delivered after Five p.m. on 31st July, 1923, will be considered.

The Town Council do not bind themselves to accept the lowest or any Tender.

No person should Tender unless thoroughly experienced in the actual construction of extensive public works.

GEORGE MITCHELL, M.Inst.C.E., F.G.S.,
Water Engineer.

Water Engineer's Office,
41½, Union Street, Aberdeen.
3rd July, 1923.

A 991

TYNE IMPROVEMENT COMMISSION.

EXTENSION OF TIMBER JETTY, HOWDON YARD.

The TYNE IMPROVEMENT COMMISSIONERS are prepared to receive

Tenders for the Extension of

a TIMBER JETTY at their Repairing Yard, Howden-on-Tyne.

Copies of the Form of Tender, Conditions of Contract, Specification and Drawing, may be obtained on application to the undersigned, on payment of a deposit of £2 2s., which will be returned on receipt of a *bona fide* Tender.

Tenders in sealed envelopes endorsed on the cover "Tender for Extension of Jetty," must be addressed to the undersigned and delivered to him not later than Noon on FRIDAY, the 20th of July, 1923.

The Commissioners do not bind themselves to accept the lowest or any Tender.

By Order,
RICHARD AUGHTON,
General Manager.

Tyne Improvement Commission Offices,
Bewick Street,
Newcastle-upon-Tyne.
2nd July, 1923.

A 993

THE GREAT INDIAN PENINSULA RAILWAY COMPANY.

The Directors are prepared to receive

Tenders for the Supply of the

following STORES, namely:—

	Fee for Specification.
CARRIAGE UNDERFRAMES and STEEL BODIES for Motor and Trailer Coaches, and with 4-WHEEL BOGIES for Trailer Coaches only...	£1

Specifications and Forms of Tender may be obtained at this office on payment of the fee for the Specification, which payment will not be returned.

The fee should accompany any application by post. Cheques and Postal Orders should be crossed and made payable to the Great Indian Peninsula Railway Company.

Tenders must be delivered in separate envelopes, sealed and addressed to the undersigned, marked "Tender for Carriage Underframes, &c.," or, as the case may be, not later than Eleven o'clock a.m., on Tuesday, the 31st July, 1923.

The Directors do not bind themselves to accept the lowest or any Tender.

R. H. WALPOLE,
Secretary.

Company's Offices,
48, Copthall Avenue, E.C. 2.
London, 4th July, 1923.

B 26

ABERDEEN CORPORATION WATER WORKS.

EXTENSIONS 1920.

CONTRACT No. 12—NEW AQUEDUCT.

The Town Council of Aberdeen are prepared to receive

Tenders from Competent

Persons willing to enter into a Contract for the MANUFACTURE and DELIVERY of about 3 miles of 40-inch diameter PIPES and SPECIALS of the following alternative types, viz.:—

(a) Cast Iron.
(b) Mild Steel (Lapwelded).
(c) Reinforced Concrete (Spun and Ordinary).

The Drawings may be inspected and Specification, Schedule of Quantities and Form of Tender obtained, on and after 12th July, 1923, on application at the Water Engineer's Office, 41½, Union Street, Aberdeen. Early application is desirable and no specification will be given out after 20th July.

For each Specification of each type a deposit of Five Pounds sterling will be required, which sum will, after a Tender has been accepted, be returned to the Tenderer, provided that he shall have sent in a *bona fide* Tender, based on the drawings, specification and schedule of quantities fully priced out in detail, and shall not have withdrawn the same.

Tenders, on the Forms prescribed, and enclosed in securely sealed envelopes, endorsed "Tender for New Aqueduct Piping" are to be addressed to the undersigned. No Tender delivered after Five p.m. on the 31st July, 1923, will be considered.

The Town Council do not bind themselves to accept the lowest or any Tender.

GEORGE MITCHELL, M.Inst.C.E., F.G.S.,
Water Engineer.

Water Engineer's Office,
41½, Union Street, Aberdeen.
3rd July, 1923.

A 990

THE GREAT INDIAN PENINSULA RAILWAY COMPANY.

The Directors are prepared to receive

Tenders for the Supply of

the following STORES, namely:—

		Fee for Specification.
1.	Firebricks	7/6
2.	Points and Crossings, &c.	5/-
3.	Brass Sheets, Copper Tubes, &c. ...	5/-
4.	Bolts, Nuts, Rivets, &c.	10/-
5.	Flanged Copper Plates, Copper Rods and Ingots	£1
6.	Platelayers' Tools	2/6
7.	Cast-iron Pot Sleepers	£1
8.	Railway Tickets	10/-
9.	Gibs and Cotters	2/6
10.	Steel Fishbolts, Chairbolts, &c. ...	7/6
11.	Crank Axles	10/-

Specifications and Forms of Tender may be obtained at this office on payment of the fee for the Specification, which payment will not be returned.

The fee should accompany any application by post. Cheques and Postal Orders should be crossed and made payable to the Great Indian Peninsula Railway Company.

Tenders must be delivered in separate envelopes, sealed and addressed to the undersigned, marked "Tender for Firebricks," or, as the case may be, not later than Eleven o'clock a.m., on Tuesday, the 17th July, 1923.

The Directors do not bind themselves to accept the lowest or any Tender.

R. H. WALPOLE,
Secretary.

Company's Offices,
48, Copthall Avenue, E.C. 2.
London, 4th July, 1923.

B 27

ENGINEERING

THE LAWS OF HEAT TRANSFER.

ALMOST innumerable experiments have been made to determine the laws of heat transfer between a hot tube and a fluid traversing it. As is often the case, however, when no adequate theory of the phenomena is at hand to guide the research, these experiments, whether made at, say, some German University with meticulous care and a lavish expenditure on equipment and on skilled assistance, or whether made by rough and ready methods in the workshop, have quite failed to do more than provide empirical formulas applicable merely to the actual conditions under which the observations were made and often hopelessly misleading if applied to other cases. An interesting illustration of how plausible yet unreliable such empirical formulas may be is provided by Fig. 1. which is based on experiments made by Mr. G. C. Webster and described in a paper published in the *Transactions of the Institution of Engineers and Shipbuilders in Scotland*, vol. lvii, page 58.

In this diagram R denotes the resistance to heat transfer between the wall of the tube and the water traversing it, as measured by Mr. Webster, who determined the actual temperature of his tube by thermocouples. The diagram shows that if we make the purely empirical assumption, that the resistance to heat flow varies as the square of the kinematic viscosity of the water, the observations plot down with remarkable regularity, and it might be inferred that the plot represented some actual physical law. As will be shown later on, however, a more complete analysis of the experiments affords very strong reasons for concluding that, when the fluid traversing the pipe is water, there is a definite but hitherto unsuspected critical point at which the law of heat transfer changes abruptly, the change being conditioned mainly by the wall temperature of the tube. For feed heaters accordingly the law of heat flow may not be the same as for a surface condenser.

The diagram reproduced in Fig. 1 was plotted down some eight or nine years ago, but the study of the results recorded in other experiments, showed that these were irreconcilable with the empirical rule suggested by Mr. Webster's observations.

A consideration of the mechanism involved indicates that the resistance to the transfer of heat between a tube and a fluid traversing it, in normal turbulent flow, must consist of two terms, one of which is independent of the thermal conductivity of the fluid, whilst the other term includes this conductivity as a factor. In its broad outlines this conclusion was reached by Osborne Reynolds many years ago. Reynolds succeeded, moreover, in deducing an absolutely rational expression for one of the two terms in question, showing that it was proportional to $\frac{v}{F}$, where v is the velocity of flow and F the frictional resistance experienced by the fluid per unit area of wall surface.* It can also be proved that this expression enters as a factor into that part of the thermal resistance which depends on

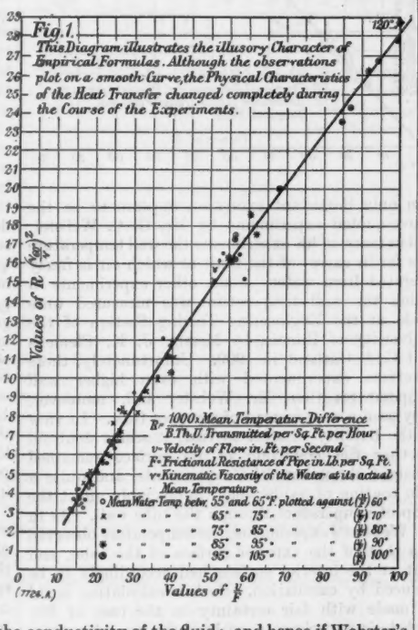


Fig. 1.
This Diagram illustrates the illusory Character of Empirical Formulas. Although the observations plot on a smooth Curve, the Physical Characteristics of the Heat Transfer changed completely during the Course of the Experiments.
Values of R (deg. F.)
Values of $\frac{\nu}{F}$
R = 1000 × Mean Temperature Difference
B.Th.U. Transmitted per Sq. Ft. per Hour
v = Velocity of Flow in Ft. per Second
F = Frictional Resistance of Pipe in lb. per Sq. Ft.
ν = Kinematic Viscosity of the Water at its actual Mean Temperature
Mean Water Temp. betw. 55° and 65° F. plotted against (ν) 60°
65° - 75° (ν) 70°
75° - 85° (ν) 80°
85° - 95° (ν) 90°
95° - 105° (ν) 100°
(7728.A)

the conductivity of the fluid; and hence if Webster's observations are plotted against $\frac{v}{F}$ we ought to get a smooth curve. What we actually do get is represented in Fig. 2 on the next page. Here it will be seen that only the observations made at low temperatures show any approach to regularity.

It appears, therefore, that some new factor made its appearance when the water temperature was high, but for long no reasonable explanation of this sudden change in the law of heat transmission suggested itself to the present writer; and the investigation was abandoned. On re-examining Webster's data some twelve months ago, however, it was noticed that the abnormal results were only recorded when the wall temperature was very high; and a possible explanation of the phenomenon then presented itself.

It has long been recognised that a considerable fraction of the resistance to heat transfer between a tube and a fluid traversing it is to be ascribed to the existence of a film of the fluid which creeps along the walls in a state of viscous flow. It will be obvious that if this film were broken up, the resistance to heat flow would be diminished, since the heat has to traverse this film by conduction and the conductivity of water is very low. If the film breaks up; the hot particles of water liberated will travel to the middle of the tube, carrying their store of heat with them, and the flow of heat from the wall to the water will be greatly accelerated. Now it has long been known that when water is heated in an open vessel and its temperature gradually raised from that of the room to the boiling point, the rate of heat transfer, which is relatively low at first, becomes quite suddenly much more rapid as the boiling-point is approached. This sudden change in the rate of heat transfer has been traced to the presence of air dissolved in the water which is but slowly liberated at low temperatures, but (when the pressure is atmospheric) becomes easily perceptible at a temperature which is stated by Osborne Reynolds* to be about 174 deg. F. (or about 80 deg. C.). This figure is confirmed by a number of careful observations by Mr. J. A. Smith described in a paper on "Air in Relation to Boiler Feeds" read before the Victorian Institute of Engineers and reprinted on page 486 of our issue of October 7, 1904.

Mr. Smith measured the volume of the gases driven out of solution when water was heated from 54 deg. F. (about 12 deg. C.) up to its boiling point. He found that up to a temperature of about 175 deg. F. there was very little evolution of the dissolved gases, but when this temperature was exceeded the gases came off freely. He gave the following figures showing the volume of gas evolved up to

Temperature, deg. F	140	175	190	200	210	212
Temperature, deg. C.	60	79·4	87·7	93·2	98·9	100
Volume of gas evolved up to stated temperature per unit volume of water (measured at 54·6 deg. F. and 29·9 in. of Hg.) ..	0·0001	0·001	0·002	0·006	0·0165	0·022

* Phil. Trans., vol. cxc. page 82.

* Scientific Papers, vol. ii, page 579.

different temperatures, when the total time taken to attain the temperature of 212 deg. F. was 2½ hours.

Now the film in viscous flow along the wall of a hot tube contains air in solution, and from Mr. Smith's experiments it appears that this air will be but slowly liberated so long as the film temperature is below some 80 deg. C. When this temperature is attained or exceeded the air comes off with fair rapidity and sets up convection currents which carry heat directly from the wall to the middle of the tube. This phenomenon involves a reduction in the resistance to heat transfer and observations in which the wall temperature is higher than this limit, may be expected to show anomalies when compared with those made at lower temperatures. Even at 175 deg. F., however, the liberation of air does not proceed with any extraordinary rapidity, and so long as the temperature of the tube wall in Mr. Webster's experiments did not exceed 180 deg. F. the observations were in good accord with those made at lower temperatures.

Mr. Smith's table shows, however, that at temperatures of over 200 deg. F. the air comes away very freely. This will have the effect of breaking up the film and the rate of heat transfer will tend to become independent of the velocity of the fluid through the tube. This conclusion seems to be consistent with the experimental results as plotted in Fig. 2. Here the low temperature observations are grouped about a straight line passing through the origin, but as the temperature rises the resistance falls off, and tends to become independent of the velocity of flow.

In the diagram, Fig. 2, the temperatures recorded are the mean temperatures of the water, but it is all important to bear in mind that the governing factor was not this mean water temperature, but the temperature of the tube wall, or rather of the film adjacent to it. Hence, as already remarked, it may be expected that the rate of heat transfer in feed heaters may be much greater than it is in the case of a surface condenser, and may follow an entirely different law.

The considerations above set forth will apply, of course, only to liquids containing gasses. No corresponding critical point is to be expected in the case when the fluid traversing the tube is a gas.

It appears, therefore, that when water containing air flows through a hot tube there are two critical conditions which affect the heat flow and change the law of transmission.

Here it may be remarked that all water generally used for cooling contains air and other gasses.

Thus consider the case of a long, hot tube traversed by water. Suppose the temperature of the water to be 0 deg. C. as it enters the tube and in the neighbourhood of the boiling point when it leaves it. It may also be assumed that on entering the tube the velocity of the water is a little below the critical value at which the flow becomes turbulent. Then for some short distance in from the entrance, the flow of the fluid will have a stream line character, and heat will pass from the wall to the centre of the tube wholly by conduction. So long as this *régime* is maintained the law of heat transfer is perfectly definite, and the distribution of temperature in the moving fluid could no doubt be determined by Fourier's analysis. As the water warms up, however, its viscosity will diminish and, as is well known, the "critical" velocity at which viscous flow changes to the turbulent type, decreases as the viscosity diminishes. Hence at some little distance from the entrance, the flow will somewhat suddenly become turbulent, and the rate of heat transfer will then be enormously increased. A method of determining the value of the critical velocity has, in fact, been based on this consideration.

As the water moves forward, not only does its mean temperature rise but the temperature of the film in viscous flow along the walls will also rise. When at any point of the tube the mean temperature of this film exceeds, say, some 80 deg. C., liberation of air from it will become so rapid that the film in question will be broken up and the law of heat transfer completely changed.

From the foregoing it would seem that any experiments intended to throw light on the rate of heat transfer in surface condensers should be so arranged that the wall temperature of the tube does not exceed 80 deg. C., and should by preference be kept well below this figure.

The considerations above set forth show how it has been possible for different experimenters to devise empirical formulas which represent very satisfactorily their own observations, but fail to represent results recorded by other investigators. Thus in the case discussed above, the water was assumed to enter the tube at such a velocity that the flow was at first non-turbulent, being of a stream-line character for some distance from the entrance. Suppose that under these conditions the mean rate of heat transfer for the whole tube is determined. If now the speed of the water be increased, the length occupied by viscous flow will be diminished, and this diminution will be a continuous function of the speed. Hence the observed rate of heat transfer will also vary continuously with the speed, and in such an experiment would provide no indication that the law of heat transfer differed in different parts of the tube. The same considerations also apply, if the film in viscous flow is broken up by the liberation of air as above suggested. The portion of the tube over which this film is thus destroyed will alter its length in a continuous manner, as the conditions are changed, and as before the variations in the rate of heat transfer will also be continuous, and may accordingly be represented extremely well by an empirical formula, which may be quite devoid of any physical significance.

In very few experiments on heat transfer has the wall temperature of the tube been measured.

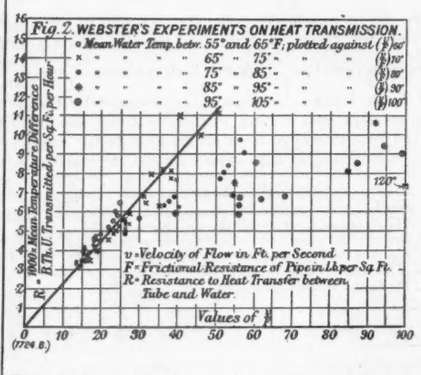


Fig. 2. WEBSTER'S EXPERIMENTS ON HEAT TRANSMISSION.
Mean Water Temp. betw. 55° and 65° F; plotted against (t)55°
65° " 75° " " " (t)70°
75° " 85° " " " (t)80°
85° " 95° " " " (t)90°
95° " 105° " " " (t)100°
1000 × Mean Temperature Difference
B.Th.U. Transmitted per Sq. Ft. per Hour
120°
v = Velocity of Flow in Ft. per Second
F = Frictional Resistance of Pipe in Lbs per Sq. Ft.
R = Resistance to Heat Transfer between Tube and Water.
Values of
0 (1764 s.)
10 20 30 40 50 60 70 80 90 100

The only important exception appears to be the above-quoted experiments by Mr. G. C. Webster, and in many of his experiments the wall temperature was far in excess of the limit at which air is freely liberated from water. Some other experiments in which the wall temperature was measured were made at the Engineering Testing Station of the University of Illinois, by Messrs. J. K. Clemens and C. A. Garland in 1909. Unfortunately, these observers experimented with even higher wall temperatures than Mr. Webster and, moreover, they used a steel instead of a copper tube. In view of the liability of steel to rust, it seems doubtful whether the condition of its surface remained constant throughout the experiments, and quite a thin coating of oxide would appreciably affect the drop of temperature through the tube wall. As in Mr. Webster's experiments, the temperature observed was that of the exterior surface of the tube, and that at the interior surface had accordingly to be deduced by calculation. Such a calculation could be made with fair certainty in the case of Mr. Webster's experiments, as his tube was of copper, but with a steel tube the probability of oxidation renders doubtful any estimate thus obtained of the temperature of the internal surface of the tube.

As already mentioned the rate of heat transmission between a tube and a fluid is calculable by Fourier's methods so long as the flow has a stream-line character. When it becomes turbulent, however, the conditions are completely altered, and it has not hitherto proved possible to establish a satisfactory connection between the rate at which heat is transferred to the fluid, and the characteristic physical properties of the latter. Some explanation of this failure appears to be afforded by the considerations above set forth, and the writer hopes to show, that on taking into account the effects of the disruption of the film, it is possible to frame a theory of heat transfer which is at once rational and in accord with the experimental data available.

As in so many other fields of inquiry of special interest to engineers, the initial steps were taken by Osborne Reynolds, who in his early work came to the conclusion that the resistance to the transfer of heat from a tube to a fluid was inversely proportional to the velocity of flow. Later on, with characteristic insight and ingenuity he greatly improved and extended this rough approximation by showing that the distribution of temperature across the radius of a condenser tube followed an exactly similar law to the distribution of the velocity. His argument,* which so far as it goes is absolutely rational, may be put in the following form.

In turbulent flow a particle of water is at one instant at the centre of the tube, and has the corresponding temperature, whilst a little later it comes close up to the tube wall and acquires the temperature there ruling. Still later the particle moves back to the centre of the tube, and this action is repeated again and again. Heat is thus transferred from the wall to the centre of the tube by the actual motion of the fluid particles.

Again, when the particle is at the centre of the tube it has a definite momentum. When it touches the wall it is brought to rest, and later on it leaves the wall again and acquires fresh momentum (for which the fall of pressure along the tube is responsible) and reaches the centre of the tube again. Hence momentum is transferred from the centre of the tube to the wall by exactly the same mechanism, as "cold" is transferred from the centre to the wall, so that the difference of momentum between the fluid and the wall is destroyed at exactly the same rate as the difference of temperature between the two.

As Osborne Reynolds showed, this concept can be put into mathematical form without much difficulty. We shall use C.G.S. units in the demonstration, as this system has special advantages whenever questions of principle are the subject of discussion, although it is, of course, desirable in the end to translate the results into engineering units. These latter, from the theoretical standpoint suffer from the disadvantage that the term "pound" is used with two entirely different significations. If we express the wall friction of a tube in pounds per square foot the term pound in this instance means a certain force, viz., that with which a specified lump of metal is attracted towards the centre of the earth. If at the same time we speak of the flow through the tube as being so many pounds per second the word pound now denotes a certain quantity of fluid, and is being used in the sense of mass, and not of weight. In the C.G.S. system this possible source of confusion is avoided. The term gramme in this system denotes always a certain mass, whilst the unit of force is the dyne, which is $\frac{1}{981}$th part of the force with which a mass of 1 gramme is attracted at the earth's surface. A pressure of 1,000,000 dynes per square centimetre is the Bar, the new standard atmosphere as used in meteorological work, and which is equivalent to 14·50 lb. per square inch. Velocities are, of course, measured in centimetres per second.

With this premise, if v denotes the mean velocity and ρ the density in grammes per cubic centimetre of a fluid flowing through a tube of area A sq. cm., the mass passing per second is ρv A, and the corresponding momentum is $\rho v^2 A = m$, say. Then if Δm be the momentum destroyed in a length of pipe Δx, and Δt be the rise in the mean temperature of the water in the same distance, we have according to Osborne Reynolds' the equality

$$\frac{\Delta m}{m} = \frac{\Delta t}{\tau - t} \quad . \quad . \quad . \quad (1)$$

where m denotes the difference between the mean momentum of the fluid and that of the wall, and $\tau - t$ is the difference between the temperature of the wall† τ and the mean temperature of the fluid t at the section considered. Let F be the frictional

* *Phil. Trans.*, vol. cxc., page 82.

† As pointed out later this definition requires a small but important correction, and strictly speaking τ should be defined as the temperature of the outer surface of the turbulent core and not as the wall temperature.

resistance at the wall in dynes per square centimetre, then the total force retarding the fluid in the section Δx is $F \pi d . \Delta x$, where d is the internal diameter of the tube measured in centimetres and F is expressed in dynes per square centimetre. This force is that which destroys the momentum Δm, but of course in steady flow new momentum is generated by the pressure gradient along the pipe, so that the velocity of flow is maintained constant. We have then

$$F \pi d . \Delta x = \Delta m,$$

whilst as already shown

$$m = \rho v^2 A.$$

Hence, substituting in (1) we get:

$$\frac{F \pi d . \Delta x}{\rho v^2 A} = \frac{F \pi d . \Delta x}{\rho v^2 \frac{\pi d^2}{4}} = \frac{\Delta t}{\tau - t}$$

Thus, proceeding to the limit, when

$$\frac{\Delta t}{\Delta x} = \frac{d t}{d x}$$

we get:

$$\tau - t = \frac{d}{4} \cdot \frac{\rho v^2}{F} \cdot \frac{d t}{d x} . \quad . \quad . \quad (2)$$

Let q be the quantity of heat (measured in calories per second) which passes through 1 sq. cm. of the interior surface of the tube wall. Then in the length Δx the total quantity passed is $q \pi d . \Delta x$, d being, of course, the internal diameter of the tube expressed in centimetres.

In one second the weight of water passing this section is $\rho v \frac{\pi d^2}{4}$ grammes, and its temperature rises by the amount

$$\Delta t = \frac{d t}{d x} \Delta x.$$

Assuming the specific heat to be unity, the total heat received by the water in its passage through the section is therefore

$$\frac{\rho v \pi d^2}{4} \cdot \frac{d t}{d x} \cdot \Delta x$$

which must be equal to the amount which has passed through the wall, *i.e.*, to $q \pi d . \Delta x$. Equating the two gives us:

$$q = \frac{\rho v d}{4} \cdot \frac{d t}{d x} . \quad . \quad . \quad (3)$$

But from (2) we see that

$$\frac{d t}{d x} = \frac{\tau - t}{\rho v^2} \cdot \frac{4 F}{d}$$

Making this substitution gives us:

$$q = \frac{\rho v d}{4} \cdot \frac{\tau - t}{d \rho v^2} \cdot 4 F = (\tau - t) \frac{F}{v}.$$

But the resistance to the heat flow is equal to the temperature difference divided by the quantity of heat passed in unit time.

Hence, calling R this resistance, we get:

$$R = \frac{\tau - t}{q} = \frac{v}{F}$$

The experiments of Stanton and Pannell at the National Physical Laboratory* have shown that the frictional resistance experienced by fluids passing in turbulent flow through smooth pipes is given by the relation $F = \rho v^2 L$, where L is entirely independent of the nature of the fluid, being given by one and the same formula, whether the fluid be viscous like tar, mobile like water, or gaseous like air. Professor C. H. Lees has, moreover, shown† that L is represented with remarkable accuracy by the expression

$$L = 0{\cdot}0763 \left[\frac{\mu}{\rho v d}\right]^{{\cdot}35} + 0{\cdot}0009$$

where μ represents the viscosity of the fluid in C.G.S. units, ρ its density in grammes per cubic centimetre, v its velocity in centimetres per second, and d the pipe diameter in centimetres. This formula holds from the critical velocity throughout the whole range of the National Physical Laboratory experiments as is well shown by the curve reproduced in our issue of May 19, 1922, page 607.

In a later paper read before the Institution of Naval Architects, in June, 1916, Professor Lees stated that the formula was also in accord with Froude's experiments on the friction of smooth boards towed through water, and it would thus appear reliable for all possible values of $\frac{\mu}{\rho v d}$ between the critical value and zero.

Substituting in equation (2) we get

$$\tau - t = \frac{d}{4 L} \cdot \frac{d t}{d x}.$$

Here $\frac{d t}{d x}$ denotes, of course, the temperature gradient along the tube. At half length of a tube it is as shown by Loeb's experiments,* nearly equal to the total temperature rise divided by the length of the tube expressed in centimetres.

Reynolds' argument is a perfectly rational one, but as formulated by its author and reproduced above, it requires one very important amendment, lacking which it fails either to represent the physical facts of the flow, or to rationalise the experimental data on heat transfer. Most writers who have discussed the theory of heat transfer have either assumed that the temperature of the surface of the turbulent core was that of the tube wall, or have assumed that the total resistance to the heat transfer was attributable solely to a film of fluid in viscous flow along the tube wall. The presence of this film has long been evident from general theoretical considerations, and a year or two ago Dr. Stanton succeeded in obtaining direct experimental proof of its existence.†

There are thus two distinct phenomena involved in the resistance to the transfer of heat from a tube to a fluid, and these phenomena obey different laws, so that any attempt to express the resistance to heat transfer by a single term was foredoomed to failure.

That the conductivity of the fluid must be a factor in the problem was recognised by Reynolds, but so far as the writer is acquainted with his writings, Reynolds does not seem to have stated exactly how it came in.

The resistance due to this film has been recognised by many, who have, however, generally tried to represent its thickness by an impossible type of formula. It can be shown by purely dimensional reasoning that if f denote the thickness of this film and d the tube diameter the ratio $\frac{f}{d}$ must be capable of being expressed in terms of Reynolds' function $\frac{\mu}{\rho v d}$.

The plan commonly adopted has been to write

$$\frac{f}{d} = C \left(\frac{\mu}{\rho v d}\right)^n$$

where C and n are constants determined by comparing the formula with experimental data. These invariably make n a positive fraction, from which it would follow that with d infinitely great the film thickness would also be infinite. We may, in fact, write the above expression in the form

$$f = C \left(\frac{\mu}{\rho v}\right)^n d^{1-n}$$

This shows that if n is positive and less than unity, f will be infinite when d is infinite. This is, of course, a physical impossibility. With d infinitely great we get a flat surface and, we know, that the viscous film which adheres to a flat board towed through water is distinctly finite and is actually very thin.

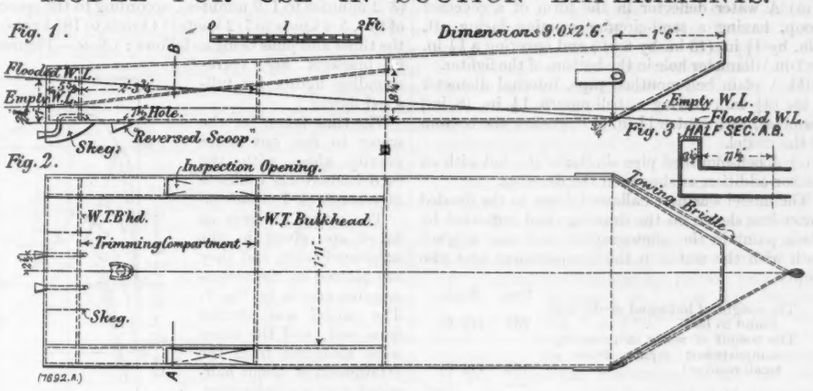
We have here an excellent illustration of a limitation to the utility of the theory of dimensions which, in fact, when taken alone, is generally insufficient to fix the form of a function representing physical phenomena. In the present instance, the theory merely shows that the ratio $\frac{f}{d}$ must be a function of $\frac{\mu}{\rho v d}$, but for the rest leaves this function indeterminate. In a succeeding article the attempt will be made to determine a more rational type of expression for $\frac{f}{d}$ by considering the physical character of turbulent flow.

(To be continued.)

* Phil. Trans. A., vol. ccxiv, page 211.
† Proc. Roy. Soc., vol. xci, page 46.

* Journal Amer. Soc. Nav. Engin., 1915.
† ENGINEERING, July 10, 1921, page 10.

MODEL FOR USE IN SUCTION EXPERIMENTS.



SUCTION EXPERIMENTS.

By P. G. ROUSE, M.I.N.A.

IT is thought that the results of some model experiments, carried out by the writer early in 1918 to demonstrate the possibility of emptying a flooded compartment under certain conditions by suction produced by towing, are perhaps sufficiently interesting to be recorded. The craft concerned were shallow-draught lighters, 58 ft. long, which had to be towed at high speed, and the conditions of service necessitated flooding and emptying a compartment aft, which when flooded and open to the sea at rest contained about 16 tons of water. The result of the model trials was that (using the corresponding figures for a full-sized lighter) at a speed of approximately 15 knots, 12½ tons of water were sucked out in 3 minutes through a 10-in. diameter hole in the bottom of the lighter, a water deflector having a semi-circular opening facing aft, 13 in. by 8 in., being fitted on the outside of the lighter covering the valve hole. The action obviously is that the water is deflected, leaving a space into which the water from the compartment runs under gravity assisted by a slight vacuum. The model tests were confirmed by subsequent trials of the full-sized lighter, the results of which are given later. The model, though flat-bottomed for convenience in making, was designed to represent very nearly the actual lighter in dimensions, after-body form, and displacement, and the results should follow the law of comparison. The length was 9 ft., that of the actual lighter being 58 ft., a ratio of 1 : 6·45, so that

model speed corresponds to V $\sqrt{6{\cdot}45}$,
model time corresponds to T $\sqrt{6{\cdot}45}$.

The suction device dimensions of the lighter were 6·45 times those of the model.

A drawing of the model is reproduced in Figs. 1, 2 and 3 above, and shows the position of the ballast compartment, whilst Figs. 4 to 6 show the three suction devices, each of which was tried separately. Four photographs are also reproduced in Figs. 9 to 12, which were taken before the most successful of the three suction devices (the reversed scoop) was fitted; they also show the two skegs fitted aft to ensure straight towing.

The three suction devices tried were as follows (the

figures given in brackets being the corresponding figures for the full-sized lighter) :—

(*a*) A water deflector in the form of a reversed scoop, having a semi-circular opening facing aft, 2 in. by 1¼ in. (13 in. by 8 in.) and covering a 1½-in. (9·7-in.) diameter hole in the bottom of the lighter.

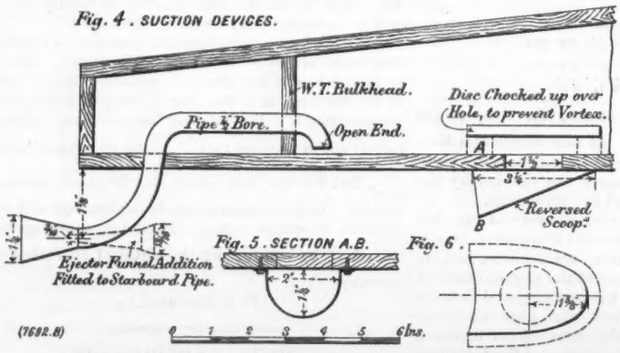
(*b*) A plain bell-mouthed pipe, internal diameter ½ in. (3¼ in.), having a bell-mouth 1¼ in. (8 in.) diameter, with centre 1⅞ in. (1 ft.) below the bottom of the model.

(*c*) A bell-mouthed pipe similar to (*b*), but with an ejector addition as shown on the drawing.

The model was first ballasted down to the flooded water-line shown on the drawing (and indicated by black paint in the photographs), and was weighed both with the water in the compartment and also empty :—

	Lbs.	Tons.
The weight of ballasted model was found to be	239	(28·6)
The weight of water in trimming compartment (apart from a small residue)	105	(12·5)
The total weight of model with water was therefore	344	(41·2)

Fig. 4. SUCTION DEVICES.



The times taken for the water to run out of the three orifices under gravity with the model ashore were also measured.

The towing was done alongside a motor boat (kindly lent for the purpose by Messrs. Thornycroft) from an outrigger, the tow rope passing over a sheave on the end of the outrigger and being secured to a spring balance inboard, which was calibrated before use. The revolution-speed curve of the motor boat was obtained by running over the Chiswick half knot.

Experiment 1.—Using the reversed scoop on the centre-line, the two pipes being plugged.

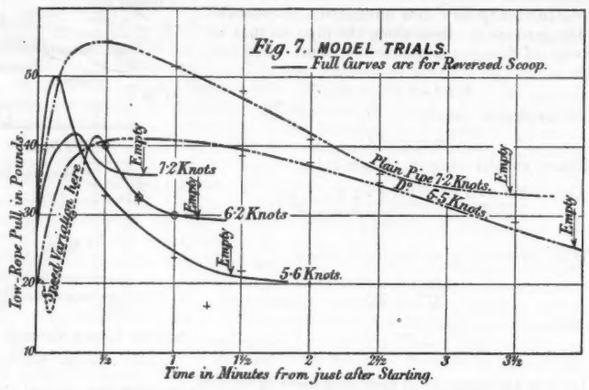
Directly the model with trimming compartment flooded was put in motion, the water began to be sucked out, as shown also by the diminishing pull measured on the spring balance, and the compartment was emptied (except for the small residue mentioned above) in from 1¼ minutes to ¾ minute (3·2 minutes to 1·9 minutes), according to the speed of tow, 5·6 knots to 7·2 knots (14 knots to 18½ knots), the times and pulls being as follows : (*Note.*—Figures in brackets are corresponding figures for full-sized lighter.)

Time from just after Start, Minutes.	Tow Rope Pull in Pounds. 5·6 Knots. (14·2.)	6·2 Knots. (15·7.)	7·2 Knots. (18·2.)
0	33 to 50	8 to 20	30 to 42
¼	42	30	—
½	33	40	36
¾	32	33	—
			Empty
1	24	30	36
		Empty	
1¼	17	29	—
	Empty		
1½	22	—	36
Time taken to empty compartment ..	1¼ min. (3·2)	1¼ min. (2·9)	¾ to 1 min. (1·9 to 2·5)

The time taken for the water to run out under gravity alone with the model ashore was 1 minute 50 seconds (4·7 minutes).

The actual readings as taken are given in the subjoined table, and they are plotted on the accompanying curves in Fig. 7. The model was started from rest, and the times were measured from the attainment of about half-speed during acceleration. (The tow boat started (slowly in the 6·2 knot run.) A fourth trial was run at about 4 knots 10·2 knots), at which speed, after part of the water had been sucked out, the action stopped and the level of the water in the compartment remained constant, the tow-rope pull also remaining constant at about 15 lb.

Experiment 2.—Using the plain bell-mouthed pipe



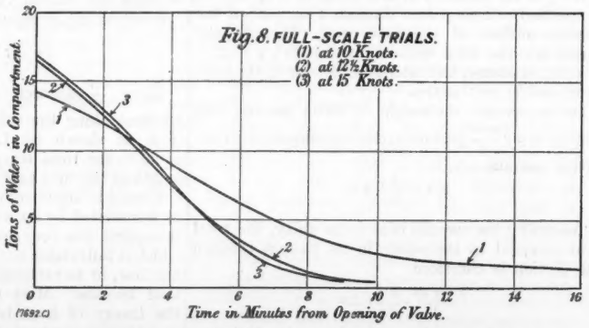


Fig. 8. FULL-SCALE TRIALS.
(1) at 10 Knots.
(2) at 12½ Knots.
(3) at 15 Knots.
Tons of Water in Compartment.
Time in Minutes from Opening of Valve.
(7692 C)

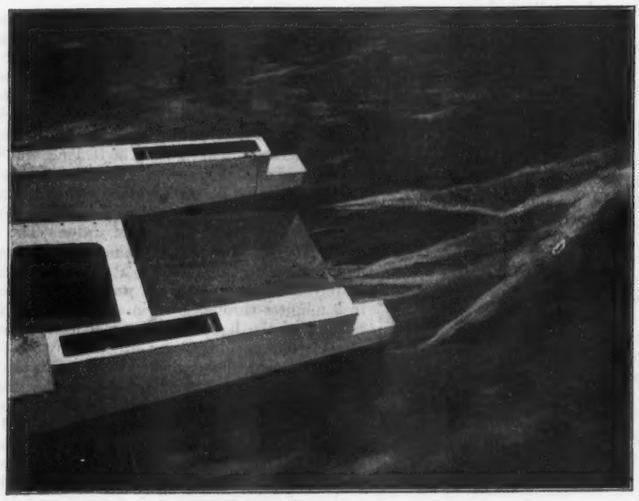


FIG. 9. STERN OF MODEL TOWED AT ABOUT 5 KNOTS.

FIG. 10. MODEL BEING TOWED AT ABOUT 5 KNOTS.

Time from just after Start, Minutes.	Tow Rope Pull in Pounds. 5·5 Knots. (14·0.)	7·3 Knots. (18·5.)
0	0 to 12	22 to 50
¼	41	55
1	41	51
1½	39	48
2	38	41
2½	35	36
3	31	34
3½	29	33
		Empty
4	25	33
	Empty	
4½	25	—
Time taken to empty compartment	4 min. (10)	3½ min. (9)

(the ejector pipe and the reversed scoop being plugged), the results were as given in the second Table on page 4.

The time taken for the compartment to empty itself through this pipe under gravity alone with the model ashore was 9 minutes 20 seconds (23·7 minutes), but the last part of the water ran out very slowly (apart from the small residue which remained behind). Although the compartment was seen to be practically empty at the end of the time given in the table referred to, it is very likely that a small amount of water was still running out, and allowance must therefore be made for this in comparing with the 9 minutes 20 seconds. This remark applies also to a less extent to experiment 1.

Experiment III.—Using the starboard pipe with ejector addition. This was not satisfactory. The cause may be faulty design of the ejector addition, but, as much better results were obtained with the plain pipe, it was considered unnecessary to experiment further with this form.

Full-Scale Trials.—As a result of the model trials one of the lighters was fitted up with a reversed scoop having a semi-circular opening aft, 13 in. by 8 in., and covering a 10-in. diameter hole in the bottom of the lighter. This hole was closed with a Kingston valve, and a grating formed of a plate pierced with small holes (total area of holes 77 sq. in.) was fitted outside the valve. Suction trials were run at 10 knots, 12½ knots and 15 knots, and careful measurements were taken of depth of water at fore end of compartment and of fore and aft inclination of lighter to the horizontal. From these measurements the curves in Fig. 8 have been made showing the rate of emptying, from which it will be seen that 15 tons of water were removed in 7 minutes at 15 knots. The time would probably have been less without the grating. In these trials steady speed was attained in each case before opening the Kingston valve, and the speed was estimated from the speed-revolution curve of the towing ship.

General Remarks.—It may be noticed that there are some discrepancies in the results described, and that the time of emptying the full-sized lighter is about twice the corresponding time deduced from the model results. It should be pointed out, however, that the trials were carried out under war conditions, and they served their purpose. The measurements were as accurate as could be made in the circumstances, but were not in all respects satisfactory as a scientific test—for instance, one of the two posts at the upper end of the half-knot course, over which the motor boat was run, had been removed. The model was made to demonstrate the application to a special craft; otherwise it would have been better to have an entirely open compartment aft, so that the removal of the water could be more closely watched. As already mentioned, the last part of the water ran out slowly, and in the case of the model it was not easy to see when it had ceased. The difference between the 12½ tons corresponding to the model and the 16 tons of the lighter is partly due to the thickness of the wood of which the model was made, and to a slight difference of form. As regards a comparison between the two suction devices 1, and 2, it is quite likely that better results for device 2 would have been obtained with the same size bell-mouth but a larger diameter pipe, but this was not tried in view of the simplicity and success of No. 1.

In any other application of these results it should be borne in mind that the action depends upon two factors, the speed and the head of water in the compartment. Another factor should be added, namely the normal effect of speed on the vessel with compartment flooded, but with orifices closed. In the present case, owing to the inclination of the bottom with compartment flooded, the hydroplane effect of towing would be to decrease that inclination, and in addition motion ahead would cause a fall of pressure behind the square stern accompanied by a fall of level of the water over the inclined deck and a consequent lift to the stern. This double effect of itself should start the emptying of the compartment through any uncovered orifice normal to the flow of water past the lighter.

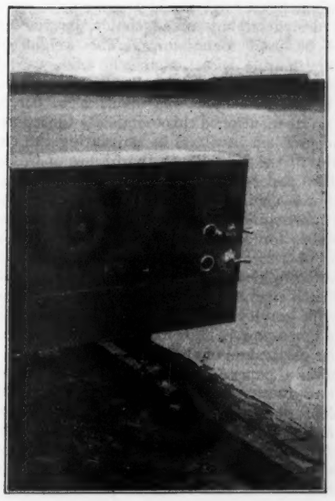


FIG. 11. VIEW SHOWING BOTTOM OF MODEL WITH THE TWO PIPES BEFORE THE REVERSE SCOOP WAS FITTED.

FIG. 12. VIEW OF MODEL ON SHORE BALLASTED TO BRING HER TO THE BLACK WATER LINE.

THE INTERNATIONAL AIR CONGRESS.

(*Continued from page* 798 *of our last Volume.*)

WE continue below our report of the proceedings of the International Air Congress, and as before give summaries of the more important papers and abstracts of the discussions ensuing thereon.

THE LANCHESTER-PRANDTL THEORY OF AEROPLANE LIFT AND DRAG.

On the morning of Wednesday, June 27th, Group A met in the reading room of the Institution of Civil Engineers, the chair being occupied by Sir R. T. Glazebrook, F.R.S. Four papers were read and discussed, the titles and authors being as follows: "The Fundamentals of Fluid motion in relation to Aeronautics," by Mr. L. Bairstow, F.R.S.; "Some Aspects of Modern Aerofoil Theory," by Mr. H. Glauert, M.A.; "The Circulation Theory of Lift, with an Example worked out for an Albatross Wing Form," by Major A. R. Low; and a note "Sur la Résistance des Fluids," by M. D. Riabouchinsky.

As the papers were all concerned with mathematical theories useful abstracts of them are almost impossible; since to be intelligible the papers should be read at length. All that we can do here is to give a general description of the subject-matter and of the special points dealt with by each author. It is now nearly a quarter of a century since Mr. F. L. Lanchester arrived at the conclusion that the motion of the air at a distance from an aeroplane was sensibly that of a perfect fluid. It has long been known, however, that a perfect fluid in irrotational motion exercises no resultant force on a body immersed in it. This matter was fully discussed by the late Mr. W. Froude in communications published in *Nature*, in 1875, where it was shown that in an infinite frictionless fluid an immersed body once set in motion would experience no resistance, but continue in motion for ever. If, however, vortices exist in a perfect fluid, which has in addition a uniform translation velocity, then at some points of the fluid the vortical motion will increase the translatory motion and at other points will diminish it. But by Bernoulli's theorem the sum of pressure head and the velocity head is everywhere the same. Hence in those regions in which the translation velocity is increased by the tangential circulation round the vortex line, the pressure will be lower than the normal, whilst conversely, where the tangential motion is in a contrary direction to the translation velocity, the resultant velocity will be diminished and the pressure correspondingly increased. We thus have in the fluid regions of high and low pressure, and in these conditions it is no longer necessarily true that the net force on a solid body immersed in the fluid is zero, and in this way Lanchester explained both the lift and part of the drag of an aeroplane. The advantage of the concept is that it becomes possible to make direct applications of the mathematical theory of hydrodynamics to aeroplane problems. The working out of Lanchester's most original views offered unfortunately no attractions to English mathematicians, and this most necessary development has accordingly been effected on the Continent, the prominent names being Prandtl and Jowkowski. In Prandtl's work the problem has been approached on the assumption that everywhere save within an infinitesimal distance from the aeroplane surface the surrounding air is in irrotational motion. He has confirmed Lanchester's conclusion that trailing vortices spring from each wing tip. These tip vortices contribute nothing to the lift of the wings, but their formation obviously involves an expenditure of energy, and the German mathematicians have been able to calculate to a fair approximation the corresponding induced drag on the machine; this induced drag is additional to the ordinary surface friction, which is all which would be experienced by a wing of infinite aspect ratio. It has, of course, long been known that a large aspect ratio is favourable to lift, but until the above work was accomplished, theory provided no means of estimating the relative efficiencies of different aspect ratios.

The above researches have been based on the assumption that save in regions close to the wing surface the air acts as an inviscid fluid. Professor Bairstow, in his paper, whilst accepting this conclusion as very approximately true, maintains that similar results should follow directly from Stokes' equations to the motion of a viscous fluid, and should it prove possible to work these out, the solutions found would have the advantage that they would be valid right up to the wing surface. It was known in fact that Prandtl's equations were unreliable near the tail, giving a lift 25 per cent. greater than the value found by experiment. He pointed out that the advantage of a fundamental solution would be that it would give us the form of the unknown function of Reynold's number, which appears in all formulas for fluid resistance. Thus it is known from dimensional reasoning that the resistance per unit area of a wing surface must be expressible in the form

$$F = \rho v^2 \psi \left(\frac{lv}{\nu}\right)$$

where the quantity in the brackets is Reynold's number, whilst ρ denotes the density and v the velocity of motion. Professor Bairstow pointed out that at present the form of the function ψ is unknown, but might, he thought, be found by fundamental researches of the type he advocated.

Mr. Glauert's paper was mainly devoted to a comparison of calculations based on Prandtl's theory, with the results of actual experiment.

From his results it appears that save near the tail there is a truly remarkable agreement between the observed and calculated pressure distribution over the wing surface. One important result from Prandtl's theory to which he drew attention was that wind channel results required correction in order to reduce them to free air conditions. In most cases these corrections were, he said, small but they were now being applied in practice. Major Low's paper was devoted to the work of Jowkowski. It is a very simple matter to calculate the flow of a perfect fluid round a cylinder, both when there is, and when there is not, circulation round the cylinder. Jowkowski showed that having determined the stream lines and velocities for this simple case it was possible to deduce therefrom the flow round a wing form. This can be done by purely graphic methods. These were only summarily described by Major Low, but he exhibited a number of highly interesting results thus obtained. In Prandtl's work it is assumed that the stream lines of the fluid follow closely the wing surface. This is undoubtedly true at small angles of attack, but at stalling angles the stream lines separate from the surface, and we get a Helmholtz surface of discontinuity, separating the main flow from the "dead water" between it and the wing. It is with this phenomena that the paper of M. Riabouchinsky was mainly concerned. He stated that he had succeeded in working out the flow of a viscous fluid through a sudden enlargement followed by a sudden contractor. It has indeed long been known that the "water grooving" frequently used for pump plungers is at best useless, and is probably in general actually pernicious. It is therefore of great interest to learn that Mr. Riabouchinsky has found a mathematical solution for the flow in very similar conditions. The paper describes solutions of a number of analogous problems, by taking into account the cavitation formed behind flat plates, past which the fluid flows. A description of an ingenious piece of apparatus for measuring the amount and "intensity" of such cavitations concluded his paper.

All four papers were discussed together, but as several of the speakers addressed their remarks to the blackboard on which they were ciphering, they were often all but naudible.

The discussion was opened by Mr. Southwell, who said that the difficulties encountered in such problems as had been discussed that morning were not mathematical merely, but were enhanced by the complexity of every case in which it might be hoped to compare calculation with experiment. Apart from the flow through pipes, there was hardly any case in which this direct comparison was possible. He suggested that owing to the fact that ν varied with the pressure, Reynolds' number might prove an inadequate basis for the comparison of the resistance of similar bodies, since the value of ν would be different in regions of low velocity from what it was at points where the pressure was higher. At the National Physical Laboratory they were testing Prandtl's theory by making use of the electric analogue to it, and mapping out the lines of force between two plates. Their wind tunnel experiments had, moreover, shown conclusively that there was circulation in the air currents past an aeroplane model, and that the observed and calculated lift were in good agreement if the lift were deduced by integrating the pressure distributed over the section. He was, however, inclined to expect that the stream line pattern would not agree with the theory. He hoped that they would be able to show why the Prandtl theory gave a correct value for the influence of aspect ratio.

Dr. Piercy, who followed, described experiments in which he had endeavoured to determine the limits within which Prandtl's theory held, by taking Pitot tube observations round wing surfaces. On the Prandtl theory, Bernoullis' theorem held everywhere save close to the aeroplane, and by Pitot tube observations Dr. Piercy determined the distance from the aeroplane surface at which the rule held, whilst at points closer than this to the surface, the Pitot tube readings were less than Bernoullis' theorem required. He had thus found that particularly near the tail end, the layer in which the total head was less than it should be was much thicker than Prandtl had assumed. He had also endeavoured to deduce from his readings the value of the induced drag due to Lanchester's tip vortices.

Mr. Von Baumhauer stated that in his own experiments he had found a very good agreement with Prandtl's theory, and he said that Continental workers were also studying the fundamental problems referred to in Professor Bairstow's paper, being fully aware of the limitations of Prandtl's theory.

In reply to the discussion Professor Bairstow said that Mr. Southwell's suggestion that Rayleigh's law of dynamic similarity was inadequate, raised the question as to how the American experiments with high values of $\frac{v\,l}{\nu}$ were to be interpreted.

Mr. Glauert said that he was satisfied of the value of Jowkowski's theory, and indeed the discrepancies of 25 per cent. which had been recorded between theory and observation were possibly due to wrong estimates of the angle of incidence. This was a very uncertain factor, and measurements of it made at different laboratories for the same wing often differed by two degrees.

Major Low thought that Mr. Glauert and himself were both to be congratulated on the fact that Prandtl's theory was now accepted in this country as being of great use. Twelve months ago it was little recognised here. He concluded with a protest against the little band of mutual admirationists constituted by the National Physical Laboratory, the Royal Aircraft Establishment and the officials at Martlesham Heath.

Dr. Glazebrook, who is an old National Physical Laboratory official, in bringing the discussion to a close, resented Major Low's protest, but congratulated him on the diagrams showing Jowkowski transformations.

AERO ENGINES.

In Group B, which met in the Council Room, under the chairmanship of Brigadier-General R. K. Bagnall Wild, three papers on aero engine subjects were read and discussed. The first of these, by Wing Commander G. B. Hynes, constituted a survey of the work recently carried out in the Engine Research and Experimental Department of the Royal Aircraft Establishment at South Farnborough. The paper first referred to the work on air-cooled engines, mentioning that two single units had been developed, the performance of which compared favourably with the best known water-cooled types with respect to power obtained, fuel consumption and reliability. From a single cylinder of $5\frac{1}{2}$ in. bore, having a piston stroke of $6\frac{1}{2}$ in., 43 b.h.p. had been developed at 1,700 r.p.m. with a petrol consumption of 0·5 lb. per brake horse-power per hour; the weight of the complete unit was 27 lb. and the maximum brake mean-effective pressure recorded was 137 lb. per square inch. Work had been carried out on supercharging and the maintenance of power at altitude, and in connection with this work a high altitude test chamber, in which the conditions of pressure and temperature prevailing at 30,000 ft. could be reproduced, has been completed. The performances of superchargers of the exhaust-driven turbo compressor and gear-driven blower types, have also been investigated in flight.

In connection with the use of heavy-fuel oil, experiments have been carried out on single-cylinder engines of the compression-ignition type arranged for solid injection of the fuel. Encouraging results have been obtained, but a satisfactory starter has still to be developed. Investigations of the torsional vibrations of crankshafts and of the breakages of valve springs have been carried out. The paper also refers to investigations made on cooling systems and radiator design, and in connection with ignition apparatus. Brief descriptions of the R.A.E. gas starting system for aero engines and of the R.A.E. electrical engine indicator, are also given in the paper. The indicator, we may mention, was fully described in a paper by Messrs. H. Wood and W. S. Smith, read before the Institution of Mechanical Engineers early this year, and reproduced on page 125 of our issue of January 26.

A paper by Mr. A. E. L. Chorlton was entitled "The Crude Oil Aero Engine," but the author explained that heavy oil would be a better designation for the fuel used, since crude oil referred to the petroleum as delivered from the well. He pointed out that by the use of fuels having high flash points the fire risk was reduced and that such fuels were cheaper than petrol and enabled higher compression ratios to be employed, thus giving lower fuel consumptions. Other advantages referred to were the elimination of the electric ignition system, positive fuel supply, and the fact that the use of heavy oil facilitated the production of the two-stroke cycle engine. All these points were dealt with in detail, and the author then compared the working of the standard aero engine having the usual low-compression constant-volume cycle, the Diesel engine with very high compression and a constant pressure cycle, and the airless-injection engine in which medium compression is employed together with a combination of the constant-volume and constant-pressure cycles. Methods of fuel injection, including the Diesel system of air spraying, the "solid," or airless, injection system and the explosion-injection system originally introduced by Brons, were discussed, as also were the effects of turbulence on combustion; several types of fuel pumps were illustrated and described. In referring to the weight of heavy oil engines, the author remarked that about 4 lb. per horse-power was the maximum figure that would be acceptable to aeroplane designers, but added that a heavier engine might be used for airships. The weight of an ordinary marine Diesel engine, he said, was of the order of 300 lb. per horse-power, while that of a modern aero engine was about 2 lb. per horse-power. He mentioned this to indicate the magnitude of the problem involved in translating the characteristics of the former into the frames of the latter, but the paper included tables of data relating to Diesel engines for submarines and to petrol aeroplane engines, which tables form a more reasonable basis for comparison. The weight per horse-power of the submarine engines is about 60 lb. A photographic illustration of the 600-h.p. Beardmore aero engine, which runs on Mexican oil having a specific gravity of 0·9, and weighs about 3 lb. per brake horse-power, is included in the paper, but no further particulars of the engine are given.

The third paper on the programme for this meeting was one by Mr. A. H. R. Fedden dealing with the problems of the static radial air-cooled aero engine. The author first explained that the limit of the air-cooled rotary engine having been reached, a demand arose in 1918 for an engine having similar characteristics but of much higher power, and with a general performance and fuel consumption comparable with existing water-cooled engines. Static air-cooled radial engines of 300 h.p. to 400 h.p. were developed, but serious failures occurred and the type received a serious set back. With the improvements since made, however, this type of engine had proved quite satisfactory, its reliability, life and fuel consumption being comparable with the best modern water-cooled engines. The weight of a 400-h.p. static radial engine, he added, was 25 per cent. less than that of the lightest water-cooled engine with radiator and water, and the power/weight ratio of the former, he thought, would be improved by a further 12 per cent. within a year. Additional advantages claimed for the static-radial engine are the elimination of inertia torque, absence of radiators and water, simplicity and convenience of gearing, and good performance under tropical conditions, while other points which may be mentioned in its favour are compactness, convenience of manufacture, rapidity of overhauling and convenience in mounting. The main causes of failures in early engines were insufficient cooling, burning and other troubles with valves, excessive fuel and oil consumptions, difficulties with big-end bearings and crankshafts, and troubles due to faulty installation. All these points are dealt with in the paper, the author referring particularly to the importance of careful installation. He also regards the matter of oil temperatures as one of vital importance, stating that for an air-cooled engine the inlet and outlet temperatures of the oil should not exceed 50 deg. and 75 deg. C., respectively. Finally the question of the maintenance of power at altitude is discussed, the author expressing a preference for the use of a high-compression engine with a bi-fuel system, or with oversize cylinders, for this purpose. Curves showing the brake horse-power of the Bristol "Jupiter" engine at various altitudes are

included, as also are other curves showing the effects of different methods of supercharging on the same engine.

The three papers were discussed together and the chairman, in opening the discussion, referred to the low-temperature testing chamber at Farnborough, remarking that very valuable results were expected from its use. It had, of course, been costly, but he thought it was unique. He called attention to the matter of repairs for aero engines, pointing out that the cost of these varied by as much as 10 to 1 in different engines, and added that the repair bill for the compression-ignition engine should be very low. With regard to the electrical indicator referred to in Wing Commander Hynes' paper, he asked what degree of accuracy was obtained and whether it was possible to obtain the mean effective pressure from all the cylinders. He agreed with Mr. Fedden as to the importance of proper installation and added that this was now fully realised.

The discussion was opened by Major F. M. Green, who, in the course of his remarks, stated that the weight of 4 lb. per horse-power given by Mr. Chorlton was too high, and engines using heavy oils would have to be much lighter to be of any service. As to the possibilities of single-row and double row static radial engines referred to in Mr. Fedden's paper, the speaker remarked that he had experienced no difficulty in cooling the double-row engine. The latter, he pointed out, had the advantage of a smaller diameter for a given power. With regard to the cooling of engines at altitude, the speaker mentioned that some tests by Dr. Gibson had shown that the effectiveness of fins increased with height, so that he thought no difficulty would be encountered in the cooling of supercharged engines at high altitudes. He thought Mr. Fedden had not fully realised the points of the gear-driven blower for supercharging, and remarked that it was a neat and simple arrangement which hardly affected the question of installation.

Several questions were asked by Dr. E. B. Wolff, and the next speaker, Wing-Commander Cave-Brown-Cave, called attention to the importance of the starting arrangements in connection with the development of the heavy oil engine. He had been surprised to hear Major Green remark that the weight of 4 lb. per horse-power was too great, and suggested that the relation between weight and fuel economy must be considered in this connection. He also inquired if the use of sleeve valves had been considered in connection with the static radial air-cooled engine. Mr. A. E. Evans referred in his remarks to the corrosion of engines in store, mentioning that this was usually attributed to the acidity of the oil. Corrosion, however, took place when a pure mineral oil with a very low acidity was used, and he suggested that the co-operation of engineers and chemists was necessary for the investigation of the matter. He queried the oil temperatures given by Mr. Fedden and thought that a much higher inlet temperature might be employed quite safely. He also expressed the view that oils should be described by viscosity and distillation tests, and not by their specific gravities. Mr. J. L. Chalmer, the last speaker in the discussion, referred, in the course of his remarks, to the matter of oil-engine nomenclature and deprecated the use of the term "solid injection."

The chairman then called upon the authors of the papers to reply briefly to the points raised in the discussion and Wing Commander Hynes, who spoke first, agreed with the chairman as to the importance of the question of repairs. With regard to the electrical indicator, he stated, that a start had been made with the indicating of all the cylinders of an engine, but that, so far, only four cylinders had been indicated on the same card. He could not give a figure for the accuracy of the instrument, but believed that it was higher than that of any other engine indicator. He explained that the cooling of a supercharged engine was a function of the air density, the forward speed, and the atmospheric temperature, and pointed out while the cooling effect of the first-mentioned quantity decreased with height, those of the other two quantities increased. He therefore thought that cooling would not present any great difficulty.

Mr. Chorlton, who then replied, explained that the term "solid injection" was in common use, but he preferred to speak of airless injection. He was also following common practice in describing fuel oils by their specific gravities. He had not stated in his paper that a heavy oil engine must necessarily weigh 4 lb. per horse-power, but that designers would not accept a greater weight than that. The question of starting raised by Wing-Commander Cave-Brown-Cave was important. He thought it was best to start by means of a barring engine with the valves lifted and run up to the speed at which ignition commences, when the valves could be dropped and firing would begin.

In the course of his reply, Mr. Fedden, in answer to Wing-Commander Cave-Brown-Cave, said that he had had no experience with sleeve valves, but added that better design and more suitable materials had resulted in considerable improvements and that very good results were now obtained with mushroom valves. In reply to Mr. Evans' query as to oil temperatures he stated that, in his judgment, those mentioned in the paper should not be exceeded.

This completed the business for the morning meeting, and, after the authors of the papers had been thanked by the chairman, the meeting was adjourned.

AIR MAILS.

Questions relating to the air transport of postal matter and the development of commercial aviation were discussed at the meeting of Group C on the morning of Wednesday the 27th ult., over which Major-General Sir W. S. Brancker presided. The two papers relating to each subject were discussed together.

The papers on this subject were presented by Brigadier-General F. H. Williamson, the British Post Office official in charge of that section of their activities and by M. le Jonkheer van den Berch van Heemstede, the secretary of the International Air Traffic Association. In the first paper Brigadier-General Williamson dealt solely with the experience of the British Post Office and with the conclusions to be drawn from it in the transport of mails by air. After referring to the pioneer activity, the institution of the London-Paris service was described. At first the traffic was small and the mail letter was regarded as comparable with a telegram rather than with ordinary correspondence. The total charge was 2*s.* 6*d.* per ounce in addition to the postage. After a few months the rates were reduced to 2*s.*, the payment of an additional 6*d.* for express delivery being made optional. When new arrangements were made between the Post Office and the carrying company in July, 1920, the air fee was reduced to 2*d.* per ounce, and the traffic was increased until 40 pounds of mail per day was carried in October of the same year. The use of the service has never kept up to the standard then set and, in fact, in 1922 was only 25 per cent. of the maximum of October, 1920, at its best.

The Post Office has in co-operation with the Air Ministry arranged for the conveyance of mails by the aeroplanes which fly between Egypt and Iraq as a part of the ordinary military aviation training. The time taken by the transmission of mail matter by ordinary services was 20 days to 23 days, and this was cut down by the aeroplane transmission to two days. There was another useful field for the combination of steamer and air carrying in the delivery of letters to the distant parts of Europe. As was indicated in the report of the Civil Aviation Advisory Board, the service to India could be shortened by several days by the use of aeroplanes flying during the day only.

The possibilities of airships still remained to be explored. As the airship can travel day and night the overall speed compared favourably with that of the day-flying aeroplanes, and with its greater carrying capacity it was not unreasonable to anticipate that for the main imperial routes the future lies with the airship. Aeroplanes would naturally serve on the branch routes as feeders for the lighter-than-air machines.

In his paper on "Transport du Courrier," Jonkheer van Heemstede advocated the use of the aeroplane in association with the other services available, namely the railway train and the steam boat. When the post was passing through the despatch office was the time to make the decision as to which of the services should be used. The two factors which should be considered in the discussion of air transport were the state of development of the technique of flying, as it affected the attainment of the indispensable requirement of punctuality in postal service and on what basis the carrying companies were to be paid for their services. The despatch of aeroplanes to a specified time-table cannot yet be guaranteed. Atmospheric conditions must be considered and there were also great difficulties associated with night flying. The system of surcharging for air transmission had not become popular because there was frequently no actual saving in time between despatch and delivery. If the transport of letters by air mail was to interest the public there must be some substantial gain in time. The departure of aeroplanes must be timed so that if flight was impossible the mails could be despatched by train or steamer. Information from the Meteorological Department would assist the carrier company to decide whether the mail should be sent by the ordinary service. Time saving was possible when the aeroplane service was worked in association with the other means of transit and without any intimation on the part of the public that mails should be sent by air. With such a scheme in operation the postal administrations would reserve a certain percentage of the carrying capacity of the aeroplanes, which would have as their principal service the transport of passengers.

Mr. de Veer opened the discussion on the two papers. The results so far obtained, he said, were not very promising, but the speed of the service must mean success in the future. Dutch experience was of a similar nature to that of Britain in regard to short distance working. Mr. H. A. Sams, of the Government of India Post Office, spoke of the hopes of commercial and political advantages to both India and the home country when air mails were established. It seemed from what had been said in a recent speech by Commander Burney that an airship could reach Bombay from Britain in 5½ days compared with 7½ days for an aeroplane. That achievement for the airship promised successful working, and better results would doubtless be obtained after the service was established, and it was to be expected that the whole of the deferred telegraphic traffic would be transferred to the airship. Other speakers emphasised the necessity for the freedom of the post offices to decide by which service the mails were sent. It was thought to be quite a wrong policy to exact surcharges and require the public to mark their correspondence "per air." Mr. Lanser thought that if the airship lines touched Norway all the mails would be sent by them. A difficulty in working in association with the postal authorities was referred to by Mr. Plesman. The suitable times of despatch were not known to the carrier companies. For effective co-operation that information was essential and he submitted a resolution which was seconded by Mr. R. H. Sams, and received with approval, that the required information should be made known through the International Air Traffic Association.

In reply, General Williamson referred to misunderstandings which had arisen regarding the time taken in the short-service runs. The delays in transit between Denmark and Britain were due to the lost time in the linking up by train and steamer. Jonkheer van Heemstede thought that when they reached the position of guaranteeing loads on the air mails they would have made a great step forward. All development must take some time but the work on the Paris-London, Cairo-Baghdad, and other routes was providing information of great value. Closer co-operation between the post offices and the carrier companies was necessary, and the International Air Traffic Association was doing much towards its attainment.

COMMERCIAL AVIATION.

Of the two papers on commercial aviation, the first was concerned with the development, based on the experience already gained, and was submitted by Messrs. F. Handley Page and W. P. Savage; while the second, presented by Colonel Cecil L'Estrange Malone, related to questions of state assistance and encouragement.

In the first paper the authors accounted for the slowness of development as due to the absence of a settled policy of Government support. Difficulties of flight at night time or in weather which brings

low-flying clouds were still to be overcome and there was no engine yet developed which could be put into a machine with any knowledge that it would run efficiently and well for a definite number of hours. Despite these troubles progress has been made and valuable experiences have been accumulated. The flying hours per machine per day have increased continuously from 1920, when the figure was 0·6, until 1922, when it reached 1·63. The experiences of 1923 have shown still further improvement, and in the month of April the corresponding value was 4·67. From October of last year until May, 1923, only 12 engine failures had been experienced on the London-Paris route. The troubles were mostly of a small character, but though connected with details they accounted for 10 forced landings. Taking 4 hours as the standard time for the London-Paris journey, the number of cases where the standard was exceeded has continuously decreased until the value for May, 1923, amounted to only 2·8 per cent. of the total. In the year ending last March, 11,460 passengers had been carried with injury to only one of them. The safety of air travel was thus comparable with that of any other form of transport.

Petrol consumption per flying hour has been reduced from between 25 and 26 gallons in 1920–21 to 20·2 gallons last year, and even better than that during the first part of this year. Petrol of the best grade was the only fuel in use, but its cost and inflammability were to be set against its continued use. It was not outside the bounds of possibility to find other fuels of more suitable characteristics.

The authors contended that the most suitable engine for commercial aeroplanes at present is one of 400 h.p. to 500 h.p., capable of running at three-fifths load for long periods and with a crankshaft speed of 1,400 r.p.m. to 1,500 r.p.m. Accessibility was of importance in the design of the details of construction of the engine. During the expansion development and research periods, Government aid must be given.

Colonel C. L'Estrange Malone, in his paper on "Commercial Aircraft and the State" suggested that the development of transport and communications had ended the strife between clans and tribes within the country, and a similar international effect must be anticipated from the extension of air routes. A bold policy extending over a period of years, of a character which would help both the State and the industry and take full advantage of research was essential. The faults in the proposals of the Civil Air Transport Subsidies' Committee, Mr. Malone thought to be the failure to take account of routes operated by other countries, or of marine work, and the monopoly subsidising of one company while the sum of 1,000,000*l.* must be regarded as inadequate for a scheme extending over ten years. The routes should be worked on an international basis. Any grant of subsidy for the development of a single route was an action showing too restricted a view. The foundation of three main routes, the first going east to India and Australia, the second running south to the Cape and the third west across the Atlantic, was desirable. In the west route use of aircraft carrying steamers, as advocated by Sir Eustace Tennyson D'Eyncourt and Mr. J. H. Narbeth recently before the Institution of Naval Architects, was necessary in the early stages. For the three routes suggested by the author the capital required would amount to something of the order of 4,000,000*l.*, and he suggested the Government should guarantee the interest at 5 per cent. on three-quarters of that sum.

The discussion, to which Messrs. Flandin and de Veer contributed largely, concerned questions of types of subsidies, and the associations of various countries to a general scheme. The suggestion of aircraft-carrying steamships some members thought not quite practicable because of the supposed difficulty of landing upon a ship in rough weather.

In reply, Mr. Handley Page suggested that the difficulties in connection with subsidies over long-distances were due to the various countries that had to be traversed. With a general scheme also there must be similarity of types of machines and of engines. Colonel L'Estrange Malone, in reply, said that it had already been demonstrated that the aeroplane steamship scheme was capable of successful application right away.

General Brancker closed the session with references to the differences of attitude of the two authors to subsidies. The one wanted to make the services pay as soon as possible, while the other sought for extended subsidies for ventures that are necessary but not economic. Despite the favour shown for the multi-engine machines the experience had shown that it was possible to make a single-engined aeroplane which was quite reliable.

TECHNICAL DEVELOPMENT OF THE AEROPLANE.

The programme of Group A for the afternoon of the 27th ult. included a paper on "The Technical Development of the Aeroplane," by Mr. J. D. North, which was read by the author in a section presided over by Colonel M. O'Gorman. Mr. North first traced the development of mechanical flight since its inception, dividing the period into four phases which he described as the pioneer age, the demonstration period, the war phase and the post-war period. The author then considered the possibilities for future advance, dealing first with the reduction of structure weight which should result from a more accurate knowledge of the external forces on a machine in flight, more reliable methods of stress computation, improvements in structural arrangements, the use of stronger materials and a reduction in overall dimensions. He did not anticipate any immediate improvement in engine weights or fuel consumption, but referred to the possibilities of re-fueling a machine in flight. In dealing with possible aerodynamic improvements, the author referred to the outstanding item of head resistance resulting from the existing arrangements for cooling the engine, which, he said, sometimes accounted for 20 per cent. of the total resistance of the machine. Another means of reducing the head resistance of large machines for transport purposes was that proposed by Professor Junkers many years ago, viz., to provide accommodation for passengers and goods in the structure of the wings. A machine of the necessary dimensions, however, would have a gross weight of about 15 tons, and it would be necessary to distribute the whole of the load along the span of the wing. Such machines he regarded as not impracticable, and he pointed out that large machines did not involve the use of very large aerodromes since machines of equal power loading and surface loading would leave the ground with the same length of run. From the point of view of safety and reliability he thought the three-engined aeroplane was most suitable for immediate transport needs, and finally he remarked that the new small aeroplanes recently developed would afford valuable data for the design of larger machines. Appendices to the paper contained an analysis of the resistances of two aeroplanes, an investigation of the relative effect of added weight and head resistance on the performance of aeroplanes, and some notes comparing the reliability of single-engined and multi-engined machines.

The reading of the paper was followed by a long and interesting discussion in which most of the speakers were in general agreement with the author. The discussion turned largely upon the question of the relative reliability of single-engined, twin-engined and multi-engined machines, Major Buchanan remarking, in this connection, that experience on the civil air routes seemed to indicate that twin-engined machines were no more reliable than those with single engines. If one engine of a twin-engined machine broke down, pilots did not attempt to complete the journey with one engine, but landed as soon as possible. Mr. F. Handley Page, in the course of his remarks, pointed out that a twin-engined machine could return to the aerodrome if one engine broke down, so that it was not necessary to land at an out-of-the-way place; the simultaneous failure of both engines, he added, was a very rare occurrence. The chairman, who also referred to this matter, said that statistics seemed to show that engine failures were proportional to the number of engines, and furthermore that the total number of accidents was proportional to the number of power-plant stoppages. He reminded the members, however, that accidents were not all equally serious and that in the case of twin-engined machines, which could choose a good aerodrome to land in, what for statistical purposes was regarded as an accident might be an incident of but little importance.

The author, in replying to the various points raised in the discussion, said, with regard to the matter of engine reliability, that the whole question of the multi-engined machine was one for the future rather than of the past. Up to the present, few people had been trained to make use of the properties of the multi-engined machine. The difficulty that pilots did not make use of the facilities provided, as pointed out by Major Buchanan, was one which could be remedied by education. Statistics based on the flying services since the war did not greatly impress the speaker, who pointed out that the value of statistics and the deductions from them was dependent upon the number of observations on which the statistics were based, adding that there were not nearly enough data available for reliable deductions to be made as to what had happened in the past. He did not think that the conclusion that the number of accidents was proportional to the number of power-plant failures would be accepted by the representatives of commercial flying.

AIRCRAFT TESTING.

The next paper taken was one by Mr. W. D. Douglas dealing with the testing of aircraft structures and components. In this the author, after pointing out the importance of such tests to the designer, referred to methods by which the testing of fittings could be simplified and cheapened by eliminating those forces which have little or no effect upon the strength of the fitting, explaining this in connection with main spar fittings and wing ribs. In dealing with the stress distribution in an aeroplane structure, the author referred to the assumptions made in order to render mathematical stress calculations possible. In this connection he gave the results of tests carried out on two similar machines, one having all the structural members in place, with the exception of the fabric, and the other having only those members which had been assumed to be present for calculation purposes. Considerable discrepancies between the calculated and measured loads were found in both cases, the calculated loads ranging from about half to more than double the measured loads for the machine tested under normal conditions. For the machine tested under the conditions used for calculations, the calculated loads ranged from 64 per cent. to 141 per cent. of the measured load. Figures given for duplicate tests of machines of the same type are in reasonably good agreement, but the designs were not identical, and the effects of modifications are noticeable. The author expressed the opinion that tests of similar machines in the new condition and after service, in order to determine the effect of ageing on structural strength, would be of little value, and that more useful information could be obtained from tests of the materials used. He discussed the effect of non-alignment of spar supports and finally gave an empirical formula for the strength of wing ribs. According to this formula, the minimum load supported before failure, should be such that $W = \frac{6{,}300\,w}{c}$ where W is the load in pounds, w the weight of the rib in pounds, and c the length of the chord in feet. This formula, the author stated, appears to be equally suitable for ribs of wood or metal construction and for load distributions, in which the centre of pressure is at $0{\cdot}28\ c$ or $0{\cdot}43\ c$ from the leading edge.

The first speaker in the discussion on this paper was Dr. E. B. Wolff, of the Ryks-Studiedienst voor de Luchtvaart, Amsterdam, who explained the method developed at that institution for measuring the deformation of aeroplane structures under load by photographic means. Photographs, he said, were taken on the same plate before and after the application of the load and it was possible to measure on the plates the deformation of the aeroplane parts and also of the structure supporting it. Mr. J. D. North, who also took part in the discussion, referred to the limitations which arose from lack of accurate knowledge of the value and distribution of the external loads. He thought there were likely to be greater errors in the assumptions of loading than in the calculations of stress. He was surprised that the strength of wing ribs followed any simple law such as that expressed by the formula given by the author, because much of the material in a rib had to be used to strengthen it sufficiently to enable it

to be handled; the greater part of the weight, in fact, was in such a position that it would not fail under test. Mr. W. L. Cowley, also expressed surprise that the formula applied without modification to ribs of either steel or wood, and the author here remarked that although he could not explain the formula, it accurately represented the facts.

The last speaker, Lieutenant-Colonel Richmond, referred to the need for practical tests on braced structures in order to check the validity of assumptions made in stress calculations for rigid airships. He also referred to the measurement of strain in structural members, mentioning that electrical strain meters depending upon the contact resistance of a series of carbon plates had been used for the purpose in the United States, and added that such instruments appeared to be applicable to the measurements of strains in the structural members of aircraft in flight.

But little time remained for the author's reply, and this was mainly occupied in dealing with the difficulties encountered in the photographic measurement of deflections, which the author said had been tried on a small scale at Farnborough. He preferred to measure the deflections by means of a level, but agreed that the photographic method had advantages in some cases. He fully appreciated the difficulty in estimating the actual loading on an aeroplane. He regretted that time would not permit him to reply to the other points raised in the discussion, but said he would do so in writing.

OSCILLATIONS OF AN AEROPLANE WING.

The last item on the programme for the afternoon meeting of the section was a report of the Ryks-Studiedienst Voor de Luchtvaart, Amsterdam, by Messrs. A. G. von Baumhauer and C. Koning, describing the investigation of the oscillations of the wing of a seaplane. The machine in which the oscillations occurred was a Van Berkel W.B. seaplane, which is of the semi-cantilever monoplane type, the pilot observing violent oscillations of the wings and experiencing heavy blows on his aileron control in flight. The oscillations died out when the attitude of the machine was changed, but were considered to be dangerous, and were therefore investigated both mathematically and experimentally by the institution above mentioned. A one-tenth scale model of the wing in question was made, the aileron, which could move freely about its hinge, being fitted with a detachable balance flap of the Avro type, as also was the full-sized machine. The oscillations were reproduced on the model in the wind channel, and it was found that there was a marked difference between the stability of small oscillations and large ones. When small oscillations were in progress, a slight disturbance of the wind would lead to a large increase in the amplitude of the oscillations. The amplitude, however, was restricted by the tapered form of the hinge slot or by the balance flap coming into contact with the wing surface. The methods by which the data required for the mathematical investigations were obtained are described and a comparison of the experimental and theoretical results is given. In general, the latter are in good agreement with the former for small angles of incidence and for small oscillations, but the agreement is less satisfactory for large angles. There are some discrepancies between the case investigated and the actual machine, and these are attributed to the occurrence of torsional oscillations in the wing of the latter. It is thought that, with an aileron of normal design, unstable oscillations cannot occur if the centre of gravity of the aileron is sufficiently far forward, and, in the case of the Van Berkel seaplane, it has been decided to alter the weight of the balance flap so as to make the centre of gravity coincide with the hinge. The machine has been tested since the alterations were made with entirely satisfactory results.

Owing to the lateness of the hour, this paper was not discussed, but the chairman expressed the hope that members would communicate in writing any remarks they had to make. After the authors had been thanked the meeting, which had been held in the lecture theatre, was adjourned.

THE CONTROL OF AEROPLANES.

Three papers were read and discussed at the meeting of Group A, held in the reading room on the afternoon of the 27th ult., the chair being occupied by Mr. R. Southwell. The first paper contributed by Mr. R. McKinnon Wood who is in charge of the section of the Royal Aircraft Establishment devoted to full-scale experiments, was entitled "Control of Aeroplanes at Low Speeds." The author said that loss of control over the orientation of an aeroplane as the incidence approached the region of stalled flight was a prolific cause of serious accidents. The aeroplane rapidly passed into the state of motion known as spin, and when this ensued the instinctive action of the pilot was to move the ailerons and rudder against the rotation and to pull up the elevators to raise the nose of the machine. As was now well known, he ought to depress the elevators, which would bring the plane out of the stalled state. With this knowledge spin lost its terror provided that sufficient height was available for recovery.

It was, however, when nearing the ground in forced landings that stalling was most likely to occur, but were complete control of the aeroplane in stalled flight secured landings could be effected safely within very restricted areas, as it did not seem impracticable to design under-carriages capable of absorbing the whole of the vertical velocity of a stalled glide. The following table gave typical figures for a biplane loaded 8 lb. per square foot, and showed the nearly constant speed of flight and inclination of the aeroplane to the horizon, and the rapid increase in the rate of descent with increasing incidence, while the last column gave the travel of shock absorber required with a uniform retardation of five times gravity:—

Incidence of Planes.	Angle of Glide.	Speed of Glide.	Rate of Descent.	—
Deg.	Deg.	m.p.h.	Ft./sec.	Ft.
10	8	62	13	0·5
15	10	54	14	0·6
20	18	53	25	2·0
30	32	52	41	5·0
40	42	50	50	8

It was possible to fly some aeroplanes in the stalled state, though the feat required skill and calm air. The provision of a very large rudder had been found of considerable assistance. Manœuvring power in stalled flight was restricted by the impossibility of increasing the lift by change of incidence, and the control sought was the power to prevent the aeroplane taking its own course after stalling.

Lateral instability was much more important in stalled than in unstalled flight, as any roll tended to increase, leading ultimately to side slipping and spin. Mr. Wood suggested that lateral control by means of non-lifting surfaces might yield a solution of the main problem of control in stalled flight, and stated that model tests had supported this view, which, however, was not confirmed by pilots who flew the modified machine. There was some prospect that considerable progress might be made by the use of Handley-Page slots as a lateral control, though these had hitherto been regarded as a device for reducing the stalling speed.

The next paper by Mr. T. M. Barlow, the chief technical officer at the Aircraft Experimental Establishment at Martlesham Heath, described the "Experimental determination of Aircraft Stability." The experiments were made in actual flight by means of a special camera, by means of which the sun was made to act as a fixed reference point. In experiments on the fore and aft stability, the aeroplane was flown directly towards or away from the sun, which by means of a cylindrical lens and slotted screen threw a point of light on to a sensitive film, moved by clockwork. The pitching of the machine was thus recorded by the curve traced by this point on the film. Lateral stability was tested in a similar way, the machine being flown at right angles to the direction of the sun, the camera being then pointed athwartships. The records thus obtained showed that the "Training" two-seater was stable at cruising or slow speeds but not at high. The single engine heavy bomber was stable only at slow speeds, but even at full speed the time period of the oscillations was such as to allow of easy correction. A twin engine heavy bomber showed very marked stability at cruising speeds, and a commercial twin engine machine was also found to be very stable. On the other hand, the records obtained with an amphibian flying boat having a pusher propeller, confirmed the view that it is practically impossible with such craft to secure fore and aft stability over a range of speed. On the basis of the records obtained, the author put forward proposals for specifying definite figures for the longitudinal stability of aircraft, which read as follows:—

All tests to be carried out in a "Steady" atmosphere, *i.e.*, free from all upward and downward currents, air pockets and clouds, and during level flight.

1. Commercial aircraft. (At slow speed and cruising speed.)

(*a*) *Uncontrolled.* With a preliminary oscillation of 10 deg. up or down from the horizontal, the oscillations shall decrease to 2½ deg. within two minutes and become normal in three minutes. During the test at no time shall the oscillations exceed 10 deg.

(*b*) *Controlled.* (At slow speed and cruising speed.) Records of level flight fully controlled shall show a maximum deviation of 1 deg. from the horizontal.

2. *Service Aircraft. Scouts, Fighters, Reconnaissance.* (At full speed and cruising speed.)

(*a*) *Uncontrolled.* With a preliminary oscillation of 5 deg. up or down, the oscillations shall decrease to 1 deg. within three minutes. At no time shall the oscillations during the test exceed 5 deg., nor shall the frequency exceed two per minute.

(*b*) *Controlled.* (At all speeds.) Records of level flight fully controlled shall show a maximum deviation of 1 deg. from the horizontal.

3. *Service Aircraft. Night Bombers.*

(*a*) *Uncontrolled.* (At all speeds.) With a preliminary oscillation of 5 deg. up or down the oscillations shall decrease to 1 deg. in 2½ minutes. At no time during the test shall the oscillations exceed 5 deg., nor shall the frequency exceed 1½ per minute.

(*b*) *Controlled.* (At all normal speeds.) Records of level flight fully controlled shall show a maximum deviation of ½ deg. from the horizontal.

The third paper was by Professor E. P. Warner, of the Massachussetts Institute of Technology, and in the absence of the author, was read by Mr. Ide. It was entitled "Notes on the Longitudinal Stability, Controllability and Manoeuvrability of Airplanes." In his introduction the author stated that it was very difficult to define satisfactorily the above terms, and that no two pilots would agree as to where the line should be drawn between ease of control and manoeuvring power. He deplored the fact that pilots were unacquainted with the mathematics of the subject, whilst the mathematicians were seldom really conversant with the problems of the designer. In commercial work stability and ease of control were paramount considerations, and manœuvring power of almost negligible importance. Such machines ought to be able to fly indefinitely under ordinary conditions, without requiring the pilot to touch the controls. On the other hand, in the case of a single-seater pursuit type of machine intended for fighting at high altitudes, stability was quite unimportant, and nicety of balance and ease of control were not of vital importance. In fact, too great ease of control might introduce dangers as the pilot estimated the severity of the stresses on his machine mainly by the force he was exerting on the controls. The ideal to be aimed at was a control arrangement which would give the maximum possible angular acceleration up to the safe limit, and would then hold this constant till the manoeuvre was completed. For many purposes the author claimed that a spring-loaded control would be advantageous.

He further suggested that the tail plane should be given a very large aspect ratio, so that part of it at least would be outside of the downwash of the slipstream, which was responsible for the fact that a machine which flies normally with the throttle open is liable to be nose-heavy with the throttle closed.

The discussion was opened by Professor L. Bairstow, who said that he would like to endorse Mr. Wood's statement that the loss of control in stalled flight was a prolific cause of accidents. It had become customary to attribute such accidents to errors of judgment on the part of the pilot, but they really arose from vices in design, and it was unfair to award the blame to the pilot who should

not be called upon to deal with such crises. One or two skilled pilots had succeeded in flying aeroplanes in the stalled condition, but it was very desirable to know how the machines actually behaved. To-day, whilst specifications laid down very definitely the load to be carried and the speed to be attained, questions of control and stability were left very open, the specification merely providing that the control and stability should be to the satisfaction of some individual named. The stability and control were, in short, undefined, because they had not been measured; and, moreover, the question arose as to in what conditions they should be measured, whether with the machine free or controlled. In the former case, the problem was complicated by the additional degree of freedom. The measurement of lateral stability presented greater difficulties than did that of longitudinal stability. From the military point of view, he agreed that stability was of minor importance, but the reverse was the case with commercial machines.

Mr. B. M. Jones said that in ordinary flight lateral stability was not a question of safety, but of convenience, and it was a question whether it was desirable. It was possible to control the rudder by a gyroscope device weighing only a few pounds, which would keep a machine on its course for a long time. The question of control at slow speeds was very important. During the war people were satisfied with a standard of safety which was too low for commercial work. From the premiums charged for insurance, it appeared that the risk was estimated at one in 1,000 for an hour's flight, and this was not good enough. We had now sufficient speed but not sufficient safety, which was compromised mainly by forced landings, the risk of which was always present. It was most important to reduce the danger attending these. In landing in a small area, some degree of crash was unavoidable, but what often happened was that in avoiding a crash into a tree the pilot stalled the machine, and so got a very much worse crash. The involuntary stall was what killed people, and hence it was very necessary to find the reason for the loss of control when the machine stalled. It had been known for three years past that machines could be flown in the stalled condition, and some critics complained that the past three years' researches had taught us nothing more. There was, however, a great difference between qualitative and quantitative knowledge, and the last three years had been devoted to finding methods of securing the latter and of representing the data acquired in an intelligible form. The stage had now been reached when it would be possible by means of wind channel and full scale experiments to find out exactly how and why an aeroplane got out of control. We should thus be able to build better machines, and might hope ultimately to construct aeroplanes not liable to stalling accidents, in which case forced landings would be merely inconvenient but not dangerous.

Mr. H. B. Irving said that there were two ways of improving stability and control, viz., to increase the control as suggested by Mr. Wood, and, on the other hand, to improve the stability by altering the characteristics of the machine, thus making the control more effective. Auto-rotation was closely bound up with spin, and at the National Physical Laboratory it had been found that by staggering the wings of a biplane, setting the upper wing forward, auto-rotation could be got rid of. The tendency could also be corrected by decreasing the gap. He admitted, however, that it did not follow that spin might be abolished in the same way, and further inquiry was necessary which was now being pursued at the Royal Aircraft Establishment. The extreme case of a staggered biplane was one with the wings set tandem, and this might have some significance with regard to the success of certain gliders. The lift diagram for a monoplane showed generally more violent stalling than the corresponding curve for a biplane. In America there had been many accidents with monoplanes, and he asked Mr. Ide if any distinct difference had been noted there between monoplanes and biplanes in regard to the danger from stalling.

Mr. Ide said that the accidents in question were not inherent to the monoplane, being mainly due to bad material and faulty lines. Fluttering at the wing tips had been common, and had been very violent in the case of the Fokker machine bought for the army.

Mr. Thurston said that during the war a sergeant was planing towards the shed, when his engine failed, and he had to choose between colliding with the shed and attempting to go over it. He decided on the latter course and the machine stalled, but, nevertheless, a perfect landing was made on the roof. The speaker had examined the machine afterwards, and there was not even a wire broken. If such feats could be regularly accomplished, safe landings could be made almost anywhere. He thought that much was to be learnt from the flyers of model aeroplanes, who often showed extreme ingenuity. They had, moreover, discovered round London certain localities in which gliding was always possible. In these models had been watched for seven minutes until they passed out of sight.

In reply to the discussion, Mr. McKinnon Wood said that at Farnborough they had not used a camera for obtaining records of aeroplane stability, but had secured similar information by noting air speeds. The plan followed was to initiate a large disturbance, and to note the subsequent air speed at intervals of 10 deg. seconds. They were thus able to determine the period of the oscillations and the damping factor. With respect to Mr. Barlow's suggested specifications he presumed that the 10 deg. initial disturbance proposed for a commercial machine meant 10 deg. up at small angles of incidence and 10 deg. down at large angles.

Mr. Barlow said that there was no reason why the present vague clauses concerning stability in aeroplane specifications should not be rendered more definite. The air speed records referred to by Mr. Wood gave merely spots, and not the complete curve, and were thus less informatory than the camera records.

Mr. Handley Page asked for further particulars as to the machines mentioned in Mr. Barlow's paper. Looking at the figures given for the speed of descent at various stalling angles, there seemed to be a point beyond which it would not pay to stall a machine. If the slotted wing made it practicable to keep the rate of fall down to 15 or 20 ft ft. per second, a chassis of reasonable dimensions could be used, but it would be difficult to build chassis to withstand higher rates of fall. The industry was, he added, much indebted for the valuable work done at the National Physical Laboratory, Farnborough and Martlesham Heath.

Mr. Southwell pointed out that in the papers it had been assumed that when the characteristics of an aeroplane had been measured separately, the two different measurements could be combined by mere super position. This was not necessarily true, but so far the principle had been found to be safe.

Mr. Wood, speaking again, said that there was no object in flying at angles much above the stalling angle, as then the velocity of descent became too great. The interest of the large angles given in the table lay in the fact that whilst attempting to fly at 15 deg. or 20 deg. the pilot might get to an angle of 30 deg.

Mr. Barlow said that he was prohibited from giving the additional data for which Mr. Handley Page had asked.

AERO ENGINE MATERIALS.

On the afternoon of the 27th inst. a meeting was held of Group B, under the chairmanship of Professor Dalby, to discuss aero engine materials and the suitability of alcohol as a fuel. The first paper was submitted by Dr. Leslie Aitchison who took as his subject "The Development of Aero Engine Materials." Strength, durability and lightness were the essential characteristics of the materials used for the manufacture of aero engine parts. Every item in an aero engine was submitted to fatigue stresses, and, consequently, a high ratio of fatigue strength to specific gravity was essential. Sufficient was known to enable the variations of fatigue range to be predicted with approximate accuracy. Under conditions of alternating stresses, the fatigue strength of aero engine steel was between 42 per cent. and 50 per cent. of the maximum stress, but the values for other alloys were not so high. It was advisable to estimate the strength value of any material in aeroplane construction on the ratio of fatigue range to weight.

As the ratio of the fatigue range to maximum strength of metal was much lower when it was cast than when forged, it was inadvisable to use castings where they could be avoided. The most dangerous type of unsoundness was that in the interior of the metal, and it was almost always produced in the casting stage of the manufacture. Unsoundness increased with the greater complexity of a casting, and there seemed to be no such thing as a perfectly sound aero engine casting of any importance. At a certain combination of size and stresses, as castings were increased in dimensions, the risk of obtaining soundness was too great for the most hardened to hazard. Steel was readily obtained in the rolled or forged form, but some of the light alloys were not so regularly wrought. Duralumin and some of the magnesium alloys which can be wrought, gave valuable mechanical properties which were useful in engine construction.

Corrosion of the external parts of an engine was best guarded against by the use of organic protectives. Erosion of valve materials varied with the composition of the steel. For valve construction the alloys of nickel and chromium offered the greatest promise. For exhaust manifolds, stainless iron proved more suitable than the ordinary kinds of steel which have been employed, but it has the disadvantage of not being suitable for welding.

Sir Robert Hadfield opened the discussion, and spoke of the improvements effected in the steel for aeroplane engines during the period of the European War. Valve troubles seemed to be due to defects which metallurgists could very likely overcome if they knew exactly what was required.

Dr. Rosenhain thought the ratio of fatigue range to weight an excellent criterion of the value of a material for aero engine construction, but other matters, such as ease of machining and resistance to shock, must not be neglected. The fatigue range to weight ratio varied with the temperature. Recent work with heat-treated Y alloy gave figures more than double that of the untreated material. The use of X-ray examinations of material was extending, and had been used for thick material with success.

Dr. Hatfield thought that the advocacy of the elimination of castings was perfectly sound, as shrinkage effects made the production of perfect castings of complicated form almost impossible. Stainless iron could be welded quite satisfactorily by any electrical method. Rustless steel afforded suitable properties for use in aircraft, and should find extended use. Mr. Chorlton suggested that the author had given what was a counsel of perfection. It must be remembered that whatever changes were effected in practice must be considered in relationship to the duties as wrought portions failed more frequently than the cast ones. Crankshafts failed more frequently than crank cases. At the conclusion of the discussion, Professor Dalby referred to the possible future development in valve steels, and to the valuable work done in another field, that of the introduction of the Y alloy.

Dr. Aitchison, in reply to the discussion, said that he did not claim the fatigue range density relationship as an absolute criterion, but it was most informative. The temperature effects on the fatigue ratio were not of much importance. X-ray examintions of structures of very large size must be regarded as impracticable. As aero engines must represent the best construction possible, the elimination of castings must be advocated. No heat treatment can possibly increase their soundness.

ALCOHOL INTERNAL COMBUSTION ENGINE.

A paper on Researches on the Alcohol Internal Combustion Engine Problems by Professor E. Hubendick, was read in his absence by Dr. Ivar Malmer. Alcohol may be produced in large quantities as a by-product of the Swedish sulphite-cellulose industry, and in consequence there was great interest in the use of spirit as fuel for engines in Sweden. There were many matters connected with the properties of alcohol and combinations of it

EXHIBITS AT THE ROYAL AGRICULTURAL SHOW.

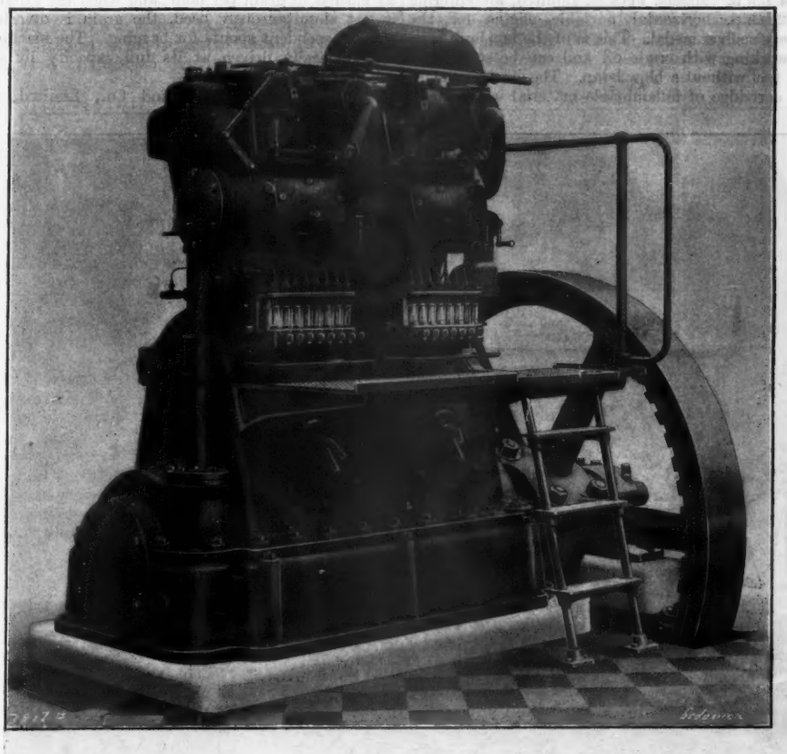


FIG. 1. TWO-CYLINDER VERTICAL OIL ENGINE; MESSRS. RUSTON AND HORNSBY, LTD., LINCOLN.

with benzene alone or with water in addition, which were not completely understood, and the author presented the results of laboratory investigations into those matters.

An interesting fact brought out in the tests was that when using 100 per cent. alcohol with dry air, it was often impossible to ignite the mixture. Alcohol stands a higher compression pressure than petrol, and temperature of ignition was raised with the dilution of the alcohol and with an increase of the excess air. As a high temperature of ignition was desirable and the air excess must be limited, a certain dilution of alcohol with water was found to be advantageous. The best rate of combustion was obtained with a mixture containing 93 to 95 per cent. of alcohol.

Sir Dugald Clerk stated that early tests showed that high compression pressures could be used with alcohol, but not perhaps so high as those used with petrol now. Professor H. B. Dixon made the discovery of the action of non-ignition of dehydrated explosive mixtures. The alcohol case was new to the speaker, but Dr. Dixon supposed, however, that all substances required the presence of water for combustion.

This concluded the proceedings on Wednesday, the 27th ult.

(To be continued.)

THE LOSS OF HEAD THROUGH VALVES.

THERE has not been hitherto very much information available as to the loss of head due to the flow of water through valves. One reason for this, no doubt, has been the impossibility of obtaining results of general applicability. The loss varies with each make of valve, and may be seriously affected by apparently quite trivial changes in the design and adjustment. Only a rough idea as to the magnitude of such losses can accordingly be afforded even by very elaborate and comprehensive experiments. Nevertheless, even crude approximations have a certain value, and hydraulic engineers in general will welcome accordingly the very extensive series of measurements of valve losses made at the engineering experiment station of the University of Wisconsin by Professor C. I. Corp and Mr. R. O. Ruble, instructor in engineering. The 48 valves tested ranged in size from ½ in. up to 12 in., and included both gate valves and the ordinary globe type. In the case of the gate valves, tests were made at various openings. Full data are given in the Engineering Series, vol. ix, No. 1 of the Bulletin of the University of Wisconsin, but as already mentioned the observations made apply only to individual tests of each valve, and must for other valves be taken as giving merely the order of the loss.

It is therefore unnecessary to reproduce here more than the general conclusions reached. In the first place the observers found that much of the total loss occurred in the pipe on the down-stream side of the valve, during the re-establishment of normal flow in this pipe. Hence measurements of the loss of head must not be made too close to a valve and the experimenters state that on the down-stream side the pressure gauge should therefore not be coupled up nearer the valve than 20 to 25 pipe diameters. The globe valves, it was found, offered from 15 to 40 times the resistance of gate valves of the same size, and the ratio was the higher the larger the value. The length of pipe occasioning the same loss of head as that caused by a valve ranges from ½ ft. to 4 ft. in the case of fully-opened gate valves and from 20 ft. to 35 ft. for fully-opened globe valves. In the case of globe valves the higher figure corresponds to the smaller valves.

THE GAS REGULATION ACT, 1920.—Detailed instructions for the provision and equipment of the testing stations required for gas examiners have now been issued from the office of the Gas Referees, and can be obtained from H.M. Stationery Office, the published price being 1*s.* net. The paper in question goes into very minute detail as to the apparatus to be provided and as to the precautions to be taken to ensure reliable results and may accordingly have an interest outside of the circles directly concerned.

THE ROYAL AGRICULTURAL SHOW AT NEWCASTLE.

THE eighty-second annual show of the Royal Agricultural Society of England, which was opened at Newcastle last Tuesday, does not appear to have been affected as much as might have been feared by the acute depression which has overtaken both the farming industry and the manufacture of agricultural implements during the last few years. The last occasion on which Newcastle was selected for the Royal Show was in 1908, and in view of the valuable work which the society is doing for British agriculture it is earnestly to be hoped that the success of that year will be repeated. The Town Moor, where the Show is held, is an excellent site and most convenient of access, being indeed quite close to the centre of the town. The live-stock entries this year almost constitute a record, being only surpassed by those at Cambridge last year, but we have to go back as far as the Cardiff Show of 1919 to find the implement section so small, whether measured by numbers of stands or by area of shedding. The intervening years, however, were rather exceptional, and with its 453 stands and 11,902 sq. ft. of shedding in the implement yard, the present show at Newcastle is not noticeably different from its predecessors. One misses, however, the brilliantly-draped composite stand of the Agricultural and General Engineers, Limited, the members of which are now exhibiting independently.

Messrs. Ruston and Hornsby, Limited, of Lincoln, are showing a large number of oil engines ranging from small petrol-paraffin engines to crude oil engines of considerable size. The latter are of the airless injection cold-starting type, designed to run on the cheapest fuels obtainable, either crude, residual or tar oils. Both horizontal and vertical engines of this kind are shown. The two-cylinder vertical engine to be seen on the stand is illustrated in Fig. 1. The cylinders are 12-bore by 17 stroke, and the engine develops a normal output of 100 b.h.p. at 300 r.p.m. Engines of this type, which are built with two, three or four cylinders, are particularly suitable for direct coupling to dynamos and are so used in many of the smaller power plants. The fuel consumption of the larger sizes does not exceed 0·42 lb. per b.h.p. hour, and with every engine sold a certificate is given showing its fuel consumption on test at various loads up to 10 per cent. more than its rated power. No blow-lamp, or previous heating of any kind is required to start these engines.

Another interesting exhibit is Messrs. Ruston and Hornsby's suction-gas pumping plant, which is entered to compete for the R.A.S.E. silver medal. The plant exhibited at the Show is capable of dealing with 1,700 gallons of water per hour, against a head of 100 ft. It comprises a single-ram pump driven through cut gearing by a 2-b.h.p. gas engine. Gas for the engine is supplied from a small charcoal producer, the consumption of charcoal being about 2·5 lb. per hour when the engine is working at its rated duty. The engine can be put on full load and pumping started within 10 minutes of lighting the fire in the producer, and attention is only required about once every 2 hours afterwards. The engine is fitted with high-tension magneto ignition, and governing is effected by variable admission. When not required for pumping, the plant can be used for driving other machinery, a pulley being fitted for this purpose. The whole arrangement is self-contained, compact and inexpensive, and the plant is suitable for domestic, general, or farm use. It is also built in a larger size capable of pumping from 3,000 gallons to 4,000 gallons per hour. In addition to the exhibits which we have mentioned, Messsr. Ruston and Hornsby, Limited, are showing centrifugal pumps, threshing and chaff-cutting machines, traction engines, road rollers, both steam and motor driven, and an oil-driven locomotive for industrial use.

Messrs. John Fowler and Co. (Leeds), Limited, of Leeds, are showing as usual examples of their heavy steam and motor-driven cable ploughing tackle. The latter has a four-cylinder engine, rated at 70 b.h.p., which is started by means of a small single-cylinder air-cooled engine. This auxiliary

engine drives a shaft carrying friction discs which can be brought into contact with the flywheel of the main engine by means of the starting pedal. Messrs. Fowler's steam and motor tackle are among the most impressive exhibits at the show, by reason of their size and power.

In addition to their well-known work in connection with mechanical cultivation of land, Messrs. Fowler have done a great deal towards the development of traction engines, road rollers and road-making machinery generally. One of their recent productions is the combined steam road-rolling, tarring and gritting apparatus illustrated in Fig. 2, above. The roller may be used in conjunction with a fixed or independent scarifier for breaking up old roads, previous to repair. It is followed by a rotary brush driven by a chain from the roller, and this again is followed by a gritting machine, as is shown in the photograph. Tar from an independent tar boiler is pumped into the side tank on the roller, where it is kept at the required temperature by means of a steam-heated coil. From this tank it is pumped to the six spraying nozzles in the cross pipe at the back of the roller. A control valve enables the amount of tar to be varied, and any of the nozzles may be shut off independently when it is desired to spray any surface less than the full normal width of 7 ft. 6 in. A flexible hose and nozzle are provided for hand spraying side paths. Tar is usually distributed at the rate of 6 sq. yards to the gallon, but the quantity may be increased or diminished according to requirements. The gritting machine has mechanical agitators which keep the grit or gravel loose and free for distribution. Granite chippings passed through a ¾ in. screen are recommended for road covering, but any screened grit can be used, the usual distribution being at the rate of 200 sq. yards to the ton of grit. As the spraying and gritting are done simultaneously, practically no inconvenience is caused to traffic, since it is not necessary to close any portion of the road. Under normal conditions, 1,200 sq. yards to 1,500 sq. yards per hour can be tarred, gritted and rolled ready for traffic.

Messrs. Petters, Limited, of Yeovil, are exhibiting a large range of their paraffin and petrol-paraffin engines, either singly or arranged for various kinds of work. Two small 50-volt electric lighting sets are shown, one of 650 watts and one of 1,000 watts output, for domestic or farm use. Other combinations include a paraffin engine driving a double-acting pump capable of delivering 1,000 gallons per hour against a head of 150 ft., a 3-b.h.p. paraffin engine and drag saw, and a portable pulping plant. Independent engines range in power from 1½ b.h.p. to 24 b.h.p. Messrs. Petters, Limited, are entering a 12-b.h.p. horizontal portable engine for the Society's silver medal. This is of the hot-bulb type for working with crude oil and can be started on that fuel without a blow lamp. The starting device is a cartridge of inflammable material which when ignited and inserted in the cylinder provides sufficient heat for starting and running the engine until the cylinder head becomes hot enough to carry on combustion. We illustrated the engine in our issue of June 1 last, page 694. Another entry for the silver medal is the combined threshing machine and grinding mill illustrated in Fig. 3, annexed. The mill plates are carried direct on the drum shaft of the thresher, which is mounted on ball bearings, and the mill can be operated either in conjunction with the thresher or independently. In the latter case the drum of the thresher acts as an efficient flywheel. The thresher will deal with about 35 bushels of grain per hour, and when the grinder is not simultaneously used, the grain is diverted into independent spouts for bagging. The machine can be easily driven at its full capacity by an 8-b.h.p. oil engine.

Messrs. Marshall, Sons and Co., Limited, of Gainsborough, show a large selection of their standard productions, including traction engines, road rollers, vertical and horizontal oil engines and threshing machinery in wood and steel. Their stand contains two vertical crude oil engines, a single-cylinder engine of 50 b.h.p. and a two-cylinder engine of similar design but double the power. This latter engine we illustrate in Fig. 4, opposite. It works on the two-stroke cycle with hot-bulb

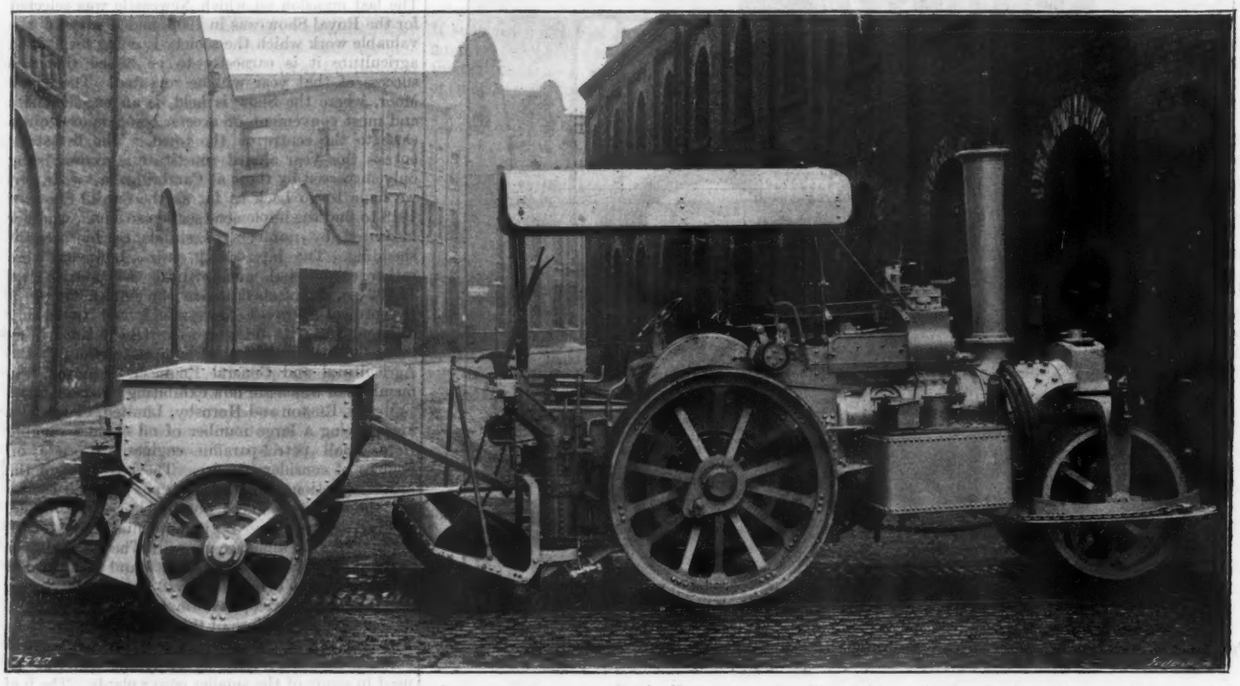


FIG. 2. COMBINED STEAM ROAD-ROLLING, TARRING AND GRITTING APPARATUS; MESSRS. JOHN FOWLER AND CO. (LEEDS), LTD.

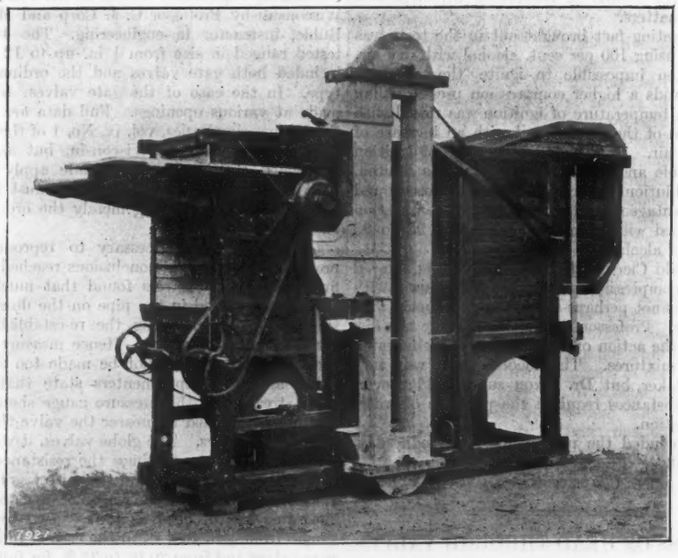


FIG. 3. COMBINED THRESHING MACHINE AND GRINDING MILL; MESSRS. PETTERS, LTD., YEOVIL.

ignition. The cylinders are 14-in. bore by 15-in. stroke and the engine develops 100 b.h.p. at a speed of 275 r.p.m. No water injection is used, and after having been started by the aid of a blow lamp the engine will run light if desired without further heating or adjustments. The absence of all valves and valve gear is an attractive feature of engines of the type in question, particularly when unskilled labour is relied on for operation. The best results are obtained with fuel oil from 0·85 to 0·9 specific gravity, but fuel heavier than 0·92 specific gravity can be used if a preheating apparatus is fitted. The consumption is stated to be less than half a pint of fuel oil per brake h.p.hr.

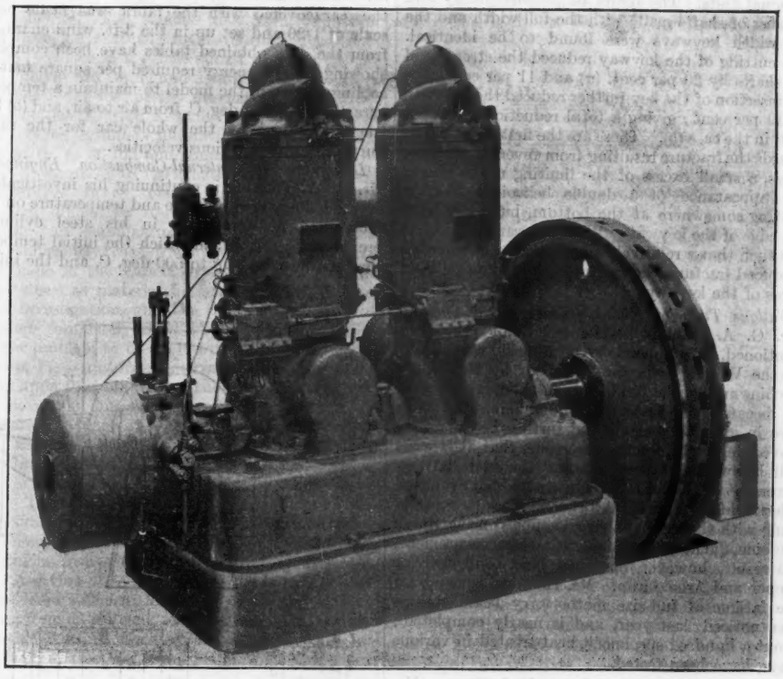


FIG. 4. 100-H.P. HOT-BULB OIL ENGINE; MESSRS. MARSHALL, SONS AND CO., LTD., GAINSBOROUGH.

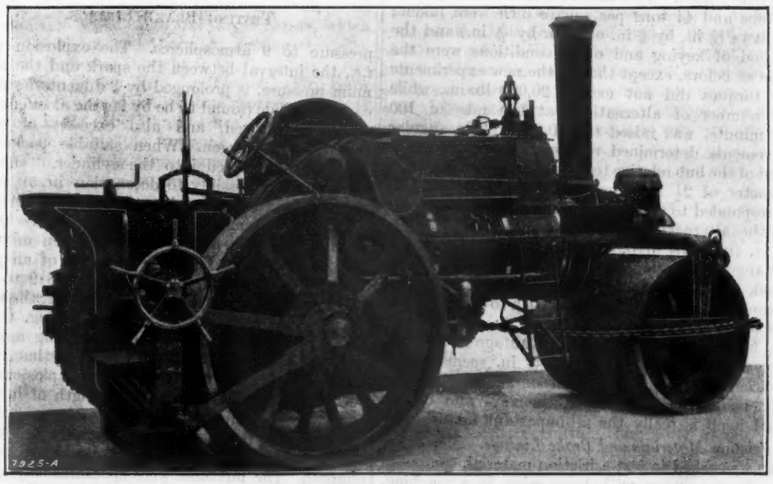


FIG. 5. 10-TON ROAD ROLLER FITTED WITH ALLEN SCARIFIER; MESSRS. MARSHALL, SONS AND CO., LTD., GAINSBOROUGH.

In Fig. 5, annexed, we illustrate a 10-ton Marshall steam road roller of a new type fitted with an "Allen" scarifier, which is also exhibited by the firm. The boiler pressure is 180 lb. per square inch; and the engine, which is of the single-cylinder type, has a piston valve with simplified radial reversing gear driven by a single eccentric. A somewhat similar roller, of 8 tons weight, driven by a compound engine, is also on the stand. In both machines, all component parts even including the boilers, are made strictly to gauge and template, so that interchangeability is assured and parts can be replaced, from stock or transferred from similar engines, without any fitting. The 8-ton roller has its power transmission gear arranged on the three-shaft principle, but four-shaft transmission is employed in the roller illustrated. Both engines have boilers fitted with Marshall's patent corrugated fire-box, which eliminates the need for crown stays and longitudinal stays between the tube plates are also dispensed with, so that the cleaning of the boilers is greatly facilitated. The scarifier shown in the illustration has a frame composed of a single steel casting embodying all necessary lugs and bearings, and the details of the design are worthy of the attention of all those interested in road-making machinery.

The National Gas Engine Company, Limited, of Ashton-under-Lyne, show a new production of theirs, namely, a 2-kw. electric lighting set illustrated in Fig. 6, page 18. The engine is of standard design, and drives the dynamo by means of a totally-enclosed silent chain and sprocket gear. The engine runs at 475 r.p.m., and the gear ratio is arranged to suit dynamos requiring speeds from 1,600 r.p.m. to 1,900 r.p.m., according to the make fitted. The low engine speed and the excellence of the workmanship of the unit make the set very attractive for country house lighting and similar work. Plants of this type are built in five sizes ranging from 1 kw. to 5½ kw. and will run either on petrol, paraffin or alcohol, or with slight modifications on town gas or suction gas.

The firm also exhibit one of their four-cylinder vertical gas engines rated at 180 b.h.p. direct coupled to a 120-kw. direct-current generator. This engine, which we illustrate in Fig. 7, on page 18, is of the four-cycle totally-enclosed forced lubrication type, which the company have developed with great success. It has cylinders, 13-in. bore by 14-in. stroke, and develops its power at 350 r.p.m. Engines of the same type are manufactured with two, three, four or six cylinders, the normal power in every case being 45 b.h.p. per cylinder. The engine exhibited is shown working in conjunction with a suction gas-producer constructed to use either anthracite or coke as fuel. The producer is of the size which would normally be supplied for an engine of from 95 b.h.p. to 110 b.h.p., but the company make suction producer plant in units up to 250 b.h.p. for gasifying not only coal and coke, but waste materials such as sawdust, wood refuse, spent tan, cocoanut shells, &c. The stand also contains a 5 b.h.p. portable suction gas engine and producer designed to use charcoal as fuel. This was originally developed for countries where the price of oil was prohibitive but where the user could make his own charcoal. The producer is a cast-iron shell without brick lining, and a simple scrubber and tar extractor are provided. The engine is of the standard National design.

(To be continued.)

THE NATIONAL PHYSICAL LABORATORY.

(Continued from page 811, Vol. xcv.)

WE proceed with our comments upon the work of the Engineering Department during the year 1922–23; references to last year's notices are to pages 7 to 9 of our issue of July 7, 1922.

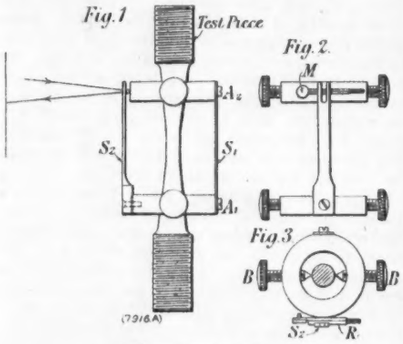
Fatigue Stress Determination from Single-Specimen Tests. (Mr. H. Gough.)—The combination method of fatigue testing, developed by Mr. Gough, was outlined last year. The essential point is that the range of stress is determined at which a definite deviation from proportionality of deflection to load occurs in the material when undergoing cyclical variations of stress. The method has been applied to reversals of torsional stress in the Stromeyer machine, to reversals of bending stress in a Wöhler machine, and to reversals of stress in the Haigh machine.

Torsional and Bending Stresses. Cyclical Strength of Copper.—How the Wöhler machine was modified for this purpose was illustrated in our article on the "Elastic Limits of Copper under Cyclical Stress" (ENGINEERING, September 8, 1922, pages 291 to 293). The Wöhler test-piece carries at its end a plane mirror fitted for adjustment in two planes at right angles to one another. When the mirror deflections are plotted against the load on the specimen, a straight line is obtained, followed by a deviation at the load corresponding to the limiting range of stress. This deviation is strongly marked in the case of ductile materials. For the further study of the effect of alternating bending stresses on the microstructure of various metals the apparatus has been modified so as to give uniform bending moment over a length of 3 in.

The Microstructure of Metals Subjected to Repeated Stress.—A joint investigation has been conducted

by Mr. H. Gough and Dr. D. Hanson, of the Metallurgy Department, into the effects of alternating stress on the microstructure of the metals. Armco iron, mild steel and copper, when subjected to reversed bending stresses, alternating direct stresses and reversed stresses. Lengthy endurance tests having first been carried out accurately to determine the limiting range of stress for these metals, the specimens were subjected to various ranges of stress, both below and above the limiting ranges, and the effects on the microstructure were observed. The photograph exhibited on the inspection day showed clearly that, with the materials used, slip occurs at ranges of stress of much less magnitude than the limiting range of stress for the materials. A full report on this important research is being prepared.

Direct Stress. (Mr. H. J. Tapsell).—In the Haigh machine tests the strain of the test-piece during reversals is measured with the aid of a Martens extensometer. The extensometer, now used by Mr. Tapsell for measurements at air temperature, is illustrated in Figs. 1 to 3. Two steel rings A_1, A_2, surround the test-piece and are held on by the



EXTENSOMETER.

gripping screws which are diametrically opposite one another in each ring. The steel rings are interconnected by two steel springs S_1, S_2; S_1 is rigidly screwed to both the rings; S_2 is screwed to A_1, but bears against A_2 with its forked upper end, the rhomb R of the extensometer mirror M being interposed; this rhomb lies in two small V grooves cut horizontally in the forked arms. The small plane mirror of the extensometer is made of stainless steel. This extensometer was first tested in a static tensile machine, and was found to give a straight line for the relation between mirror deflection and strain on the test-piece. The new device eliminates any source of error which might occur with the extensometer first used, due to un-axial loading; it also gives a larger scale reading. The first extensometer was fitted with only one ring (the lower one) and one spring (corresponding to S_2). The materials tested show a divergence from the straight-line law at points coincident with the fatigue ranges as obtained by the endurance method.

During the progress of an alternating stress test the temperature of the test-piece rises. This rise is measured by the aid of an iron-constantan thermo-couple, soldered to the centre of the test-piece, and it has been found that the temperature rise, slow below the fatigue range, becomes rapid above that range. The determinations of the fatigue range by the yield method at higher temperatures have been pushed up to 700 deg. C.; the test-piece is surrounded by an electric furnace which consists of two parts joined along one side; the heaters of each part are two vertical windings of nichrome wire on mica sheets forming two mats, one surrounding each half of the central portion of the test-piece; the four terminals are brought to the top of the furnace. A couple of platinum/platinum-rhodium is used in this case.

Keyways and Shafts under Torsional Stress. (Mr. Gough.)—The effect of keyways on the strength and stiffness of shafts is being studied by determining the relative limiting ranges of torque under reversals of load for a solid shaft, a shaft with a standard keyway and a shaft with a keyway of equal depth and half the width of a standard keyway, with or without the key in position. The stiffness and limit of proportionality of the three types of specimen under load are likewise determined. The shafts are model shafts of 0·4 in. diameter, made (*a*) of a 0·65 carbon steel, (*b*) of Armco iron, (*c*) a dead mild steel, the width and depth of the keyway being 0·109 in. and 0·036 in., or half this width at the same depth. A Martens extensometer is used for the static tests, and the Stromeyer machine for the torsional tests. The limits of proportionality and stiffness of shafts made with the full-width and the half-width keyways were found to be identical. The cutting of the keyway reduced the strength of the shafts by 20 per cent. (*a*) and 11 per cent. (*b*); the insertion of the key further reduced the strength by 19 per cent., giving a total reduction of 30 per cent. in the case (*b*). These are the first results. As regards the fracture resulting from reversed shearing stress, a small excess of the limiting range caused the appearance of a double helicoidal fracture starting somewhere at the bottom, but away from the edge of the keyway. When the range of torque was such that a relatively small number of reversals produced fracture, the fracture occurred along both edges of the keyway.

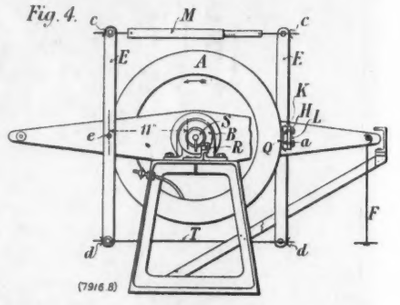
Fatigue Tests of Nickel. Lorry Beam Springs. (Mr. G. A. Hankins.)—The tests, not previously mentioned, of commercially pure nickel carried out by the Wöhler endurance method, by the Haigh machine and by the yield range method, are interesting because the results of the different methods were in good agreement, and further because they proved definitely, for the first time, that at stresses well below the fatigue limit of the material any increment of stress may produce a sudden evolution of heat which gradually dies away. The observation, made with the help of thermo-couples on the Haigh machine, did not admit of quantitative measurement; the result, however, has since been confirmed for copper and Armco iron. Mr. Hankins' research on the fatigue of full-size motor lorry beam springs was noticed last year, and is nearly completed; about a hundred specimens, heat-treated in various ways, have been tested.

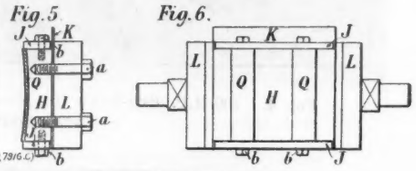
Resistance of Keys to Reversal of Stress. (Mr. Batson.)—The research of 1914 was resumed at the request of the British Engineering Standards Association with materials harder than the mild steel previously used. Two bars of ultimate strengths of 32 tons and 44 tons per square inch were taken; the keys ($\frac{5}{8}$ in. by $\frac{5}{8}$ in. or $\frac{5}{8}$ in. by $\frac{7}{16}$ in.) and the method of keying and other conditions were the same as before, except that in the new experiments the torques did not exceed 20,000 lb.-in., while the number of alternations, at the rate of 100 per minute, was raised to 500,000. The angular movements determined represent the total movement of the hub relative to the shaft, and with a shaft diameter of $2\frac{1}{2}$ in. a movement of 0·008 radian corresponded to 0·01 in. at the surface of the shaft. As the alternating torque was raised from 5,000 lb.-in. (in steps of 5,000 lb.-in.) to 20,000 lb.-in., the angular movement rose from 0·00015 to 0·0031 (weak steel, and small key) and from nil to 0·0028 (strong steel, large key) radian. Up to 15,000 lb.-in. the larger keys appeared superior to the smaller; at higher torques that advantage vanished. Generally a key of $\frac{5}{8}$ in. by $\frac{7}{16}$ in. seems to be sufficiently strong for a shaft of $2\frac{1}{2}$ in. But the refinement of the fitting of the keys and of the shaft itself is really the all-important feature.

Friction Materials and Brake Linings.—Mr. Jakeman was asked to test a friction material, composed of asbestos woven with brass wire, in a machine, supplied by the makers of it, in which a strip of the material encircled half of a cast-iron wheel turned by an electric motor. The wheel became so hot that samples of the materials were destroyed during the first tests with the temperature rising to 300 deg. C. The machine was, therefore, modified as indicated in Figs. 4 to 6. The flywheel A has trough-shaped rim for the circulation of water, the temperature of which is determined. The test-piece Q is pressed against the wheel by means of the holder H, a packing strip K, the loading block of cast-iron L and the screws *a* and *b*, and is further held in position by the end plates J. The whole machine is mounted in a cradle; B marks the bearing of the shaft S, E the loading levers, F the friction scale pan, M the spring balance, and *c* and *d* adjusting nuts.

Skin Friction and Heat Transmission from Heated Walls.—In her continued experiments made in the new 5-in. wind channel, Miss D. Marshall studies the effects of air turbulence on the heat transmission from the surface of a pipe. A cognate problem set by the Aeronautical Research Committee concerned the loss of heat through the doped fabric constituting the walls of an airship passenger car. A model of the car covered with the fabric was made on a scale of 1/20 and set up in the 3-ft. wind channel; from the data obtained tables have been compiled showing (*a*) the energy required per square foot of cooling surface in the model to maintain a temperature difference of 1 deg. C. from air to air, and (*b*) the energy required by the whole car for the same purpose, both for various velocities.

Detonation in Internal-Combustion Engines.—Mr. R. W. Fenning is continuing his investigation of the influences of pressure and temperature on the production of detonation in his steel cylinder, previously described, in which the initial temperature can be raised up to 500 deg. C. and the initial





TESTING BRAKE LININGS.

pressure to 9 atmospheres. The explosion time, *i.e.*, the interval between the spark and the maximum pressure, is prolonged by "diluents" such as carbon dioxide (found to be by far the most effective diluent), nitrogen, and also excesses of either hydrogen or oxygen. When suitable pockets or passages were fitted into the cylinder, "shocks" corresponding possibly to detonation in an engine cylinder were produced; the shocks were not noticed after removing the pockets. These experiments were made with hydrogen-oxygen mixtures. In the liquid fuel tests the strength of air-petrol mixtures was varied by adding from 8·9 to 19·7 parts of air to 1 part by weight of petrol, the initial temperature and pressure being 100 deg. C. and 95 lb. per square inch absolute; strong mixtures gave a "knock" late in the explosion time, which was long compared to the hydrogen explosions, and the knock increased with the strength of mixture. Both initial temperature and pressure are factors in favouring detonation, but temperature is the predominant factor, especially in high density charges. The mixtures were spontaneously ignited when the temperature of the cylinder walls reached 250 deg. C.

Ventilation of the House of Commons.—Mr. A. Bailey's experiments on the mode of ventilation of the House of Commons, made with the aid of a model of 1/8 scale, which we mentioned last year, were questioned by H.M. Office of Works, the point raised being the applicability of the law of similarity to the case of a building in which the circulation was maintained in a particular manner. Further experiments were, therefore, made on the flow of air through circular orifices and measurements taken of the variation of the velocity at the centre of the jet with increasing distance from the plane of the orifice. These experiments having confirmed the

applicability of the law, the research was continued, and a modification of the ventilation has been proposed. The whole of the gratings under the side and cross benches are to be closed, and the air is to be admitted through openings on the front of the side galleries, and partly also through some openings in the central portion of the floor (gangway); the air is to be extracted again through the small slots under the side galleries and through some additional ducts placed along the underside of the side galleries. The scheme has been approved. It is intended that the main ventilating currents should circulate in a gentle vortex from the gallery level downward and up again, but not from underneath the feet of the members in their seats.

Gas Cylinders. (Mr. A. Bailey.)—The new type of light oxygen cylinders for medical work, weighing from 32 lb. to 36 lb., and containing 40 cub. ft. of gas at pressures up to 120 atmospheres, have proved satisfactory. In the elastic limit tests of whole cylinders difficulties were, however, experienced because the manufacturers' cylinders were not found sufficiently true; trial cylinders have therefore been made in the Laboratory. The suitability of nickel steels as material for such cylinders is also under investigation, and the thermal expansion of cylinders completely filled with liquefied gases is another problem to be dealt with.

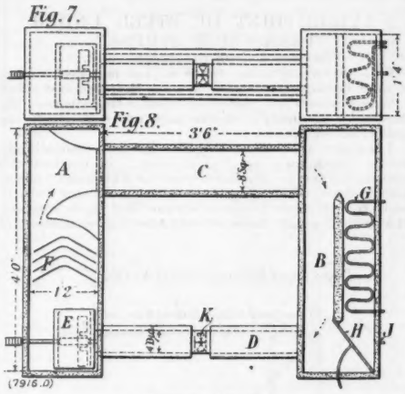
Steam Pipes and Pipe Coverings. (Mr. Jakeman.)—The apparatus for testing the efficiency of steam pipe coverings for superheated steam, which we illustrated on page 155, of our issue of August 4, 1922, has been in full demand. A test occupies from three to five days, and during that period three observations have to be taken at different temperatures. There is likewise a strong demand for tests of the coverings for pipes carrying saturated steam, low-pressure steam and hot water; one Government department insists upon the Laboratory standard test. A saving of 85 per cent. of the bare pipe loss is considered sufficient for these covers, and savings ranging from 60 per cent. to 88 per cent. are actually realised. Tests of some expansion pipes, of 6 in. and 5 in. diameters, were made with the pipes empty and with the pipes filled with water at 200 lb. per square inch; the compression of the expansion pipe at high temperature can then be calculated from the results of the low-temperature test. The actual behaviour of a pipe largely depends, of course, upon the thickness of the metal on the outside of the bend, and this thickness, which can hardly be measured without drilling the pipe, may be half of what it ought to be.

Laboratory Drying Kiln for Timber. (Mr. Hankins.)—At the request of the Forest Products Research Board, Mr. Hankins has, in conjunction with Dr. Ezer Griffiths, designed a forced-draught drying kiln of fairly large ranges in the rates of circulation, in temperature and humidity. Figs. 7 and 8 illustrate the working model-kiln in plan and elevation. The fan E sends air through a series of electric resistance mats F into the heating chamber A, which is 4 ft. long and 14 in. square and is provided with a curved baffle wall as shown. Parallel to A is the cooling chamber B, of the same dimensions, and the two chambers are cross-connected by the drying chamber C, which is 3½ ft. long and 8 in. square, and the return pipe D in which the anemometer K is inserted. The cooling chamber B is so subdivided by means of a partition wall and the flap door H, that an adjustable portion of the air may return directly to the fan, while another portion is sent over the outer surfaces of the condenser coil G through which cold water is circulating. When high humidity is required, steam is admitted into B through the inlets J. The speed of the air circulation can be raised to 5 ft. per second and the temperature to 80 deg. C. Little attention has so far been paid in this country to artificial timber drying, which is not neglected in America.

Road Research Division. (Mr. Batson.)—The asphalt mixing plant made by the Ransome Machinery Company, was described last year. In order to control the bitumen accurately three boilers have been provided, one for heating the flux, the second for heating the bitumen as supplied, and the third for mixing the flux and bitumen in order to secure the desired penetration number; to the third boiler the Laboratory has added a special stirrer. The demands for tests of road stones have increased, and kerbs and flagstones are being tested by request of the Ministry of Transport for density and water absorption, for crushing and transverse bending, in the dry and soaked conditions, also under impact, and for resistance to abrasion; the materials submitted are natural stone, sand, lime and concrete.

Tramcars. (Mr. Hyde.)—Tests have been conducted on behalf of the Hoffmann Manufacturing Company, on a London County Council tram car, before and after replacement of the plain bearings of Hoffmann roller bearings, and have subsequently been supplemented by tests made at Sheffield and Glasgow with other cars and bearings. The London car was of the standard double-deck roof-covered type, especially selected as a freely-running car; the weight empty, 15 tons 17 cwt., was brought up by means of sand bags to the full 78 passenger car weight of 20 tons 14 cwt. The car was equipped with two 63-h.p. motors and series-parallel interlock controllers. The electric power consumption, tractive resistance (dynamometer tests), starting effort and coasting properties were determined under varying conditions by service runs at half-load and full load, stopping at fixed "stop by request" stations, on level tract and hills. Some 60 miles have been run in the trials. When the car was half loaded and was stopped at fixed stations the ball bearing effected a power saving of 30 per cent., with full load and stopping at all stations the saving was 23·6 per cent.; the starting effort was reduced by 75 per cent. and even 80 per cent.; that last figure, of course, applies to a very short period only, but there is a very substantial saving in the general service.

Fig. 7.



DRYING KILN.

(*To be continued.*)

THE INSTITUTION OF MECHANICAL ENGINEERS.

(*Concluded from page 809 of our last Volume.*)

DOCK APPLIANCES.

ON the meeting being resumed on the morning of Wednesday, June 27, the first paper to be taken was one by Mr. Daniel Fife, entitled "Modern Dock Appliances at Glasgow Harbour, including the Handling of Grain in Bulk, also Dredging Plant." We commenced reprinting this paper in our last issue (page 820 *ante*) and continue it on page 32 of our issue this week. As time was short the discussion was curtailed.

Mr. W. Reavell congratulated Mr. Fife on the courage he had shown in introducing so many novelties in connection with his pneumatic elevating plant. One of the notable features consisted in fitting turbo exhausters with automatic control to a portable plant. It would not perhaps be readily realised why such a control was desirable. When the nozzle was not buried in the grain, as in cleaning up, a rush of air passed to the turbo machine which became momentarily overloaded. The automatic control was designed to meet this condition. It would be seen from Fig. 9 of the paper that with a drop from 3,580 r.p.m. to 2,800 r.p.m., although there was a considerable drop in vacuum the volume of air aspired was maintained nearly constant, the difference in volume being only about 300 cub. ft. to 400 cub. ft. per minute. A great economy of power was secured by means of the control. As a matter of fact if to-day they had to repeat the machine he thought they would be able to improve upon it. His firm had taken up the Maag system of gearing. It was very efficient and very silent in running. Its main feature was a larger proportion of rolling motion and less sliding than with ordinary gearing. On a portable plant such as was described by Mr. Fife, a simple system of air cooling for oil was preferable to water cooling with its necessary pipes and connections.

Mr. C. Bentham said the pneumatic elevating plant possessed features not adopted before, and the paper gave for the first time complete data regarding the performance of such a plant. It was the first time also that the automatic scale recorder had been used. It would be noted that a diagram (Fig. 10) gave a section of a curve for cleaning up which indicated a consumption of power of from 3½ h.p. to 4 h.p. per ton lifted. That was for a particular case and he would not like people to go away with the idea that that power was always necessary—it was very exceptional. Table V of the paper gave actual figures which showed 1·26 h.p. to 1·71 h.p. per ton lifted, and a note stated that the higher figure was for trimming with pipes on the floor of the hold. The higher figure of 3½ h.p. to 4 h.p. was very rarely met with in practice. In Table VI of the paper, item E, regarding capital cost, showed 10,000*l.* for the bucket elevator and 30,000*l.* for the pneumatic plant. He would like to know whether the 10,000*l.* was for a pre-war plant as his experience went to show that nowadays there was very little difference between the capital costs of both types of machines. With regard to item A of the same table, it should be noted that the bucket elevator rated at 250 tons capacity, averaged a rate of about 75 tons, *i.e.*, about 30 per cent. of rated capacity, while the pneumatic plant rated at 100 tons averaged about 85 tons, or 85 per cent. of its rated capacity. It was not contended that the pneumatic type of plant was economical on power, but it was claimed for it that it was much more effective. An instance of this was given in the paper in connection with the three days' saving effected in ship's time. The pneumatic plant did all the difficult jobs.

WATER CONTROL AND DISTRIBUTION.

After a vote of thanks to Mr. Fife the next paper considered was by Mr. E. Bruce Ball, on "Improvements in Mechanical Contrivances in Connection with the Storage and Distribution of Water." This paper we commence to reproduce on page 27 of this issue. The only speaker on the paper was Mr. R. W. Allen, who said that he thought the diffuser described was a very fascinating development. He had been wonderfully impressed by the diffusion effects in the great mass of water which passed over Niagara Falls. People seldom realised what water control meant nowadays. The Nile was controlled from its source to the sea, a length of 3,500 miles, and it was known practically to a gallon what was passing down the river. Quite recently he had visited the Calioub Barrage, north of Cairo. Here the engineer-in-charge had to report on the river level and had devised a combined telephone and gramophone instrument which, when rung up, gave a verbal report gramophonically of the exact depth of water.

MARINE OIL ENGINES.

Owing to lack of time Professor Mellanby's paper on "Clyde Marine Oil Engines" was summarised only by the author, the discussion thereon being held over till the autumn session in London. This paper we shall hope to reproduce in an early issue. As the title implied, Prof. Mellanby devoted his paper to details of the various types of marine oil engines constructed in the Clyde district. He also drew attention to points of design which had presented difficulties in the past. Four-stroke cycle designs were considered first, and this part of the paper covered the Burmeister and Wain, the North British Diesel Engine, and the Beardmore-Tosi designs. The two-stroke engines described were the Sulzer, the Cammellaird-Fullagar and the new North-British Company's engine to which

we referred in our last issue. The Scott-Still combination type was also included.

Votes of thanks to all those who had contributed to the entertainment of the Institution or had given facilities for the holding of the meetings or visits to the works, &c., were then passed enthusiastically and the session terminated. The afternoon, as already reported, was spent in visiting various works, the list of works thrown open to members being too lengthy to detail. It must suffice to state that all members received the greatest possible attention and thoroughly enjoyed the hospitality extended to them.

THE INSTITUTION DINNER.

On Wednesday evening the Institution dinner was held, the president, Sir J. Dewrance, K.B.E., being in the chair. Mr. W. H. Patchell proposed the toast of "The City and Trade of Glasgow," this being responded to by the Lord Dean of Guild, Sir F. C. Gardiner. Sir Henry Fowler proposed "Technical Education and Kindred Societies," responded to by Professor Magnus MacLean and Mr. H. E. Yarrow, the latter pleading for more co-operation and co-ordination between the several technical societies represented in Glasgow. The toast of the "Institution" was proposed by Sir John Hunter, K.B.E., and replied to by the President, who dwelt mainly upon the topic raised by Mr. Yarrow, and upon education.

As already reported, Thursday was spent in whole-day excursions, while Friday was spent in various visits to works, thus concluding a very pleasant visit to the city, favoured fortunately by good weather.

"THE BRITISH STANDARD PORTLAND CEMENT SPECIFICATION."

TO THE EDITOR OF ENGINEERING.

SIR,—May I call your attention to a slight error which has crept into your issue of June 22, in which, on pages 779 and 780 ("Notes"), you kindly comment on the points raised in my recent paper on the "British Standard Specification for Portland Cement."

On page 780 it is stated that "The British specification requires for the seven days' tests 400 lb. per square inch for the neat cement, and 150 lb. per square inch for the sand cement mortar"; these figures are those of the original 1904 specification, which were raised in 1917 to 450 lb. and 200 lb. respectively, and are still in force in the current 1920 edition.

I trust you will excuse my calling attention to the error, which might possibly mislead some of your readers.

Yours truly,
D. B. BUTLER.

6, Earl-street, Westminster, London, S.W. 1.
June 26, 1923.

"THE ORIGINAL UNIFLOW STEAM ENGINES."

TO THE EDITOR OF ENGINEERING.

SIR,—It is with very great interest I have read the letter from your correspondent, Mr. Chas. R. King, M.I.C.E.(Fr.), relative to the above subject.

I may, perhaps, mention that I have in my possession the original steel plate engraving of my great grandfather's compound uniflow steam engine patented in the year 1827. This engine appears to have taken steam from a water-tube boiler, working at a pressure of from 800 lb. to 1,000 lb. per square inch.

Yours faithfully,
LOFTUS PATTON PERKINS, M.I.J.E.

17, Skardu-road, Cricklewood, London, N.W.
June 25, 1923.

"HOT AIR SUPPLY TO BOILER FURNACES."

TO THE EDITOR OF ENGINEERING.

SIR,—Referring to your leading article in last week's ENGINEERING, this is very interesting to me. Some years ago I was concerned in checking an elaborate attempt to apply it to Lancashire boilers. The attempt was a failure, not because the principle was wrong, but because the passages were too small to carry the necessary amount of hot expanded air, at the pressure used. My present interest is with the same subject in reheating and annealing furnaces. In designing, running and checking up such furnaces, I find there is a gain in efficiency, when hot air is properly applied, far away above that represented by the heat in the air.

This point you make something of and to my mind is very important. It is by making complete combustion, without excess air, possible, that the gain in efficiency is made. Combustion cannot be efficiently completed by mixing cold air with the gases from either coal fires or from producers, particularly when impinging on cold metal, as we all know. Where I have been able to work out the heat balance, for cases in which I considered hot air properly applied, I have found the air used was practically down to the theoretical amount. I have found no difficulty in keeping down the flame temperature.

In no case have I run a job with the hot air under the firebars, partly because of the troubles well known to engineers, and partly because I have found it can be successfully applied later. I wonder if the gain in efficiency, extra to that represented by the heat in the air, is affected when the hot air is passed through the bars?

Yours truly,
C. H. COMPSTON.

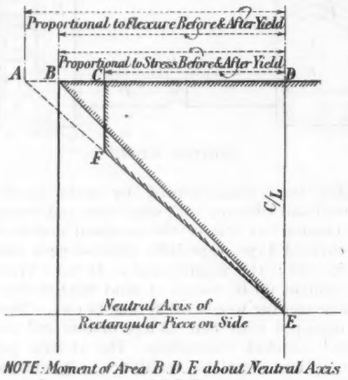
Llanelly, July 3, 1923.

"YIELD-POINT OF STEEL UNDER TRANSVERSE STRESS."

TO THE EDITOR OF ENGINEERING.

SIR,—Referring to my letter in your last week's issue it may be well specifically to note that the statement I make relates to *post*-yield conditions, whereas Sir Alexander Kennedy's results have reference chiefly to *ante*-yield conditions.

I suspect that what happens is, that immediately before breakdown, or "yield-point" is reached the stresses do not greatly differ from Sir Alexander's calculated values, there being no material molecular disturbance though there is elastic strain—but upon reaching the critical point there is complete disorganisation of



NOTE: Moment of Area B D E about Neutral Axis equals " C D E F " "
i.e. Moments of Resistance immediately before and immediately after "Yield" are equal.
(1923)

structure in the outer layers, with collapse to the condition of ductility, and a drop in maximum stress towards the normal yield value for a considerable depth from the outer layers, from which depth to the neutral axis the material remains under elastic law at a somewhat higher stress than before obtained at this depth. The moment of resistance before, and immediately after, breakdown must be of equal amounts, corresponding to support of the same load, it being understood that the provisional assumption as to stress area B D E (see figure) is itself in question.

It will be apparent, however, that precise knowledge of the stress developed at any stage is of little value without an equally precise knowledge of available resistance.

Yours truly,
W. H. THORPE.

12, Buckingham-street, Strand, London, W.C. 2.
July 2, 1923.

MINING IN THE FEDERATED MALAY STATES.

THE total export of metallic tin, plus 72 per cent. of ore, from the Federated Malay States, amounted in the year 1922 to 35,286 tons. The average London three months' quotation for the year was 160*l.* 14*s.*, and the average Straits price 158*l.* 1*s.* per ton. These figures compare with prices of 168*l.* and 166*l.* 13*s.* 4*d.* for 1921. The local price at the end of 1922 was 179*l.* 16*s.* The labour force employed on mining at the end of the year was 82,195, compared with 86,339 in 1921. About 90 per cent. of the labour employed was Chinese. Labour was cheap and plentiful. The total acreage alienated for tin mining, exclusive of unsurveyed concessions, was 216,561 acres, a decrease of 2,878 acres as compared with 1921. The consumption of fuel by the industry amounted approximately to 103,916 tons of coal, 2,640 tons of oil and 701,137 tons of firewood. Fuel was fairly easily obtained, and the prices ruling were considerably below in the case of coal, and level with those of 1921 in the case of firewood. Thirty-four prospecting licences covering an area of 42,142 acres were issued, but only 458 acres were selected. The proportion of the total output from lode mining was 6·8 per cent. for the year under review, compared with 5·6 per cent. in 1921 and 9·6 per cent. in 1920. As in former years, the bulk of the output from lode mining came from one mine, that of the Pahang Consolidated Company, Limited, at Sungei Lembing. Bucket dredges accounted for 15·2 per cent. of the total output, this figure showing a slight increase over that for the previous year. At the end of the year there were 33 dredges in operation and 9 under construction. The number of new dredges proposed to be built in the future is roughly, as far as is at present known, 20. More attention is being paid to costs and efficiency in the working of these dredges. Bucket dredging remains the most popular form of mining, but there are indications that the suction cutter type of dredge may supplant it.

The total export of tungsten ores of Federated Malay States origin as shown by the Customs returns was 95 tons in 1922, as compared with 55 tons in 1921. Practically the whole of this ore was wolfram. The export duty on these ores remained in abeyance.

The quantity of Federated Malay States gold placed on the market was 15,005 oz., and the value of gold produced at market rates was 67,525*l.*, compared with 59,097*l.* in 1921. The Raub Mine alone produced 12,929 fine ounces.

The output from the Malayan Collieries, Limited (Selangor), was 281,828 tons, as compared with 299,351 tons in 1921. Of this, 154,097 tons was consumed by the Federated Malay States Railways, 72,678 tons by the mines and 33,112 tons were exported.

Boring for oil near the mouth of the Bernam River, by United Plantations, Limited, continued, but without success, work on the third bore being suspended in September, after reaching a depth of 540 ft. It is stated that work will be resumed early in the current year.

The Malayan China Clay and Pottery Company, Limited, was devoting most of its attention at the end of the year to the production of latex cups for which there is a large demand on the rubber plantations. During the year 350,000 cups were sold. The market for china clay was not so good as previously, owing to strikes in Bombay, strong competition in the Indian market by Cornish producers, and the local high cost of freight. Machinery for producing the materials for making all kinds of pottery was being installed at the end of the year and production should commence shortly.

FRENCH DISTINCTION AWARDED SIR ROBERT HADFIELD.—At the meeting of the French Academy of Sciences, which was held in Paris on June 7, Sir Robert Hadfield, Bart., F.R.S., was elected a corresponding member, Chemical Section, of that academy, in recognition of the extensive scientific research work he has carried out.

ROYAL INSTITUTION.—A general meeting of the members of the Royal Institution was held on Monday afternoon (July 2), Sir James Crichton-Browne, treasurer and vice-president, in the chair. The death of Sir James Reid, Bart., was reported to the meeting, and a resolution of condolence with the family was passed. Mr. R. N. Lennox was elected a member.

IRON AND STEEL INSTITUTE.—Sir William H. Ellis, G.B.E., D.Eng., managing director of Messrs. John Brown and Co., Limited, has been nominated by the Council of the Iron and Steel Institute for election as president next year. He will assume office at the May meeting of the Institute in 1924, in succession to Mr. Francis Samuelson, of Thirsk, who has been president since 1922.

PERSONAL.—Messrs. Owen and Dyson, Limited, Rother Iron Works, Rotherham, have removed their London office from 15, Victoria-street, to St. Stephen's House, Victoria Embankment, Westminster, S.W. 1.—The United Strip and Bar Mills, Limited, have removed their London Office from 15, Victoria-street, to St. Stephen's House, Victoria Embankment, Westminster, S.W. 1.—Messrs. Flannery and Given, Limited, consulting engineers and naval architects, have removed, as from July 1, to Drury Building, 21, Water-street, Liverpool. (Telephone number and telegraphic address remaining the same.)

MANGANESE STEEL WELDING RODS.—Welding rods of manganese steel, says *The Iron Age*, New York, have recently been introduced, and are claimed to be successful in the welding of manganese steel, or the building up of worn manganese steel parts. They are being manufactured by the Manganese Steel Forge Company, Real Estate Trust Building, Philadelphia, under the name of "Rol-Man" manganese steel rods. The rods are claimed as especially suited for the welding of electric steel and railway parts, for the repair of manganese steel frogs, crossings, lay-outs and special track work, and for rebuilding worn manganese steel wearing parts in mills, crushing plant, cement mills, &c.

THE LATE MR. JAMES GOLBY BARFORD.—We regret to have to announce the death, which occurred on June 29, of Mr. James Golby Barford, chairman of Messrs. Barford and Perkins, Limited, Peterborough. Mr. Barford was in his sixty-second year, and was the son of the late Mr. William Barford, J.P., one of the founders of the firm. He was educated privately and at Christ College, Finchley; he then spent a year in Austria previous to serving his apprenticeship with Messrs. E. R. and F. Turner, Limited, Ipswich. From 1905 up to the time of his death, Mr. Barford was a member of council of the Smithfield Club; he was a prominent life member of the Royal Agricultural Society, and a member of council of other kindred societies. During the war he was actively connected with the Red Cross. When Messrs. Barford and Perkins combined their interests with the Agricultural and General Engineers, Limited, Mr. Barford was elected to the Board of the parent company.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—The difficulty with which steel-makers and engineering concerns are faced at the moment is not so much that of obtaining new business, but of arranging contract prices which leave a reasonable margin of profit after covering oppressive working costs. Of one sort and another, there is an abundance of inquiries for materials and steel products, but values are so severely cut all the way round that much of the work on offer not only would yield no profit, but offers prospect of a definite loss. Evidence of this is found at individual works. One concern with a record output last year of 159,000 tons of ingots, as compared with the previous maximum aggregates of 150,000 tons in 1921, made a working loss of 140,000*l.* owing principally to competitive influences reducing prices of work in hand to an uneconomic level. Much the same obtains in regard to tools and implements. A few big orders have been placed on export account for files and saws, and there is a healthier demand for twist drills and milling cutters, but inquiries representing in the aggregate a far larger tonnage have failed to materialise because of the inability to arrive at satisfactory contract arrangements. The brighter side is represented in the receipt of a substantial order for land boilers and for industrial plant. The contract placed by the Consett Iron Company with Messrs. Davy Brothers will furnish a year's constant employment for 1,000 men, will benefit 500 operatives in allied branches, and will necessitate the reinstitution of the continuous production system. The home collieries are improving buyers of all classes of pit gear and coal-cutting apparatus. Marked development is reported in the extension of coal working areas, more coal-raising machinery is being erected, and more coke ovens are being lighted up. Concurrently, schemes are in operation to provide extended housing facilities for pit workers. No further reductions are shown in official quotations of raw and semi-finished materials, but the tone is weaker, and lower prices would readily be conceded if cheaper fuel were available.

South Yorkshire Coal Trade.—While the local market presents several active features, the prevailing undertone is quiet. Heavy tonnages of best steams are still going away to the Continent *via* Hull under unexpired contracts, but new business is somewhat sluggish, and on home industrial account midsummer stock-taking operations are interfering with development. Stocks at works, however, are low, and users must soon be forced into the market to cover commitments. Weakness tends to spread in cobbles and nuts, though slacks are still scarce. House coal is uniformly dull. Quotations:—Best branch handpicked, 32*s.* 6*d.* to 34*s.* 6*d.*; Barnsley best Silkstone, 28*s.* to 30*s.*; Derbyshire best brights, 25*s.* 6*d.* to 27*s.* 6*d.*; Derbyshire best house, 23*s.* to 24*s.* 6*d.*; Derbyshire best large nuts, 20*s.* 6*d.* to 22*s.* 6*d.*; Derbyshire best small nuts, 18*s.* to 20*s.*; Yorkshire hards, 21*s.* to 23*s.*; Derbyshire hards, 20*s.* to 22*s.*; rough slacks, 12*s.* to 14*s.*; nutty slacks, 11*s.* to 13*s.*; smalls, 7*s.* to 9*s.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Another cut in prices of Cleveland pig-iron has brought customers into the market once more, but though there is much improved inquiry, actual business is still on only a very limited scale. No. 1, owing to its continued great scarcity, is nominally upheld at 125*s.*, but No. 3 g.m.b. is now in a good deal more than ample supply, and is selling at 110*s.*; whilst Foundry 4 is very plentiful and is offered freely at 105*s.* There is not a great deal of No. 4 forge available for disposal in the open market, most makers using the output at their steel furnaces, and the price is put at 102*s.* 6*d.* All the foregoing quotations are f.o.t. makers' works, or f.o.b. Tees.

Hematite.—Makers of East Coast hematite declare that further fall in prices must be speedily followed by damping down of furnaces, as already quotations are unremunerative. For substantial orders on either home or export account producers are prepared to accept 110*s.* for mixed Nos., but for small lots the price is in the neighbourhood of 111*s.* 6*d.*

Blast-Furnace Coke.—Durham blast-furnace coke continues to command 41*s.* 6*d.* delivered, though local consumers consider the figure much too high.

Manufactured Iron and Steel.—Orders for finished iron and steel are difficult to secure and manufacturers are quite prepared to make price concessions. Ship-plates, angles, joist and railway material are all down in price. Among the principal market quotations are:—Common iron bars, 12*l.*; iron rivets, 14*l.*; packing (parallel), 8*l.* 10*s.*; packing (tapered), 11*l.* 10*s.*; billets (soft), 10*l.*; billets (medium), 10*l.* 10*s.*; billets (hard), 10*l.* 15*s.*; steel boiler plates, 14*l.*; steel ship, bridge and tank plates, 10*l.*; steel angles, 9*l.* 10*s.*; joists, 9*l.* 15*s.*; heavy steel rails, 10*l.*; fish plates, 14*l.*; black sheets, 13*l.* 10*s.*; and galvanised corrugated sheets, 18*l.* 10*s.*

Shipments of Iron and Steel from the Tees.—Official returns show that, including 1,507 tons of pig-iron cleared at Skinningrove, shipments of iron and steel from the Tees last month reached 77,633 tons. Of the 24,367 tons of pig-iron loaded at Middlesbrough, 17,597 tons went to foreign ports and 6,770 tons went coastwise; of the 1,796 tons of manufactured iron despatched, 1,384 tons went to foreign ports and 412 tons went coastwise; and of the 49,963 tons of steel cleared, 36,766 tons went to foreign ports and 13,197 tons went coastwise. The largest importers of pig-iron were: United States, 5,545 tons; Wales, 5,380 tons; Germany, 4,240 tons; France, 1,257 tons; Canada, 1,100 tons; and Belgium, 1,031 tons. Once more India was the heaviest receiver of both manufactured iron and steel, taking 916 tons of the former and 11,632 tons of the latter. Amongst other principal importers of steel were: Canada, 3,818 tons; Japan, 2,970 tons; Nigeria, 2,714 tons; Victoria, 2,225 tons; Egypt, 1,455 tons; New South Wales, 1,403 tons; and the Argentine, 1,369 tons.

Iron and Steel Imports to the Tees.—Returns issued this week give imports of iron and steel to the Tees from Holland, Belgium, France, Norway, Sweden, Germany and coastwise for the eight months ending June 30 last, as compared with the same time a year ago, and with the corresponding pre-war period of 1913–14. The quantity of pig-iron brought in for the eight months to the end of June totalled 5,557 tons, as against 32,552 tons a year ago, and 218 tons for the pre-war period. Plates, bars, angles, rails, sheets and joists unloaded to the end of June last amounted to 8,549 tons, as against 4,229 tons a year ago, and 17,419 tons for the pre-war period. Crude sheets, bars, billets, blooms and slabs imported to the end of June reached 49,881 tons, as against 41,288 tons a year ago, and 30,307 tons for the pre-war period.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—The week corresponding to this in most former years was usually a very busy one at the steel works in Scotland hurrying forward orders prior to the holidays, but there is no such pressure just now as business is so slack. Consumers, except in a very limited number of cases, are showing little anxiety to get supplies before the annual closing down at the end of next week. Contracts on hand have kept plant running during recent months, but fresh bookings are still of a very poor nature, with the result that the future is not very bright. Inquiries both on home and export account do not hold out much hope for producers, and the situation in the Ruhr district is largely responsible for the conditions prevailing here to-day. Prices are being maintained at last levels and are as follow:—Boiler plates, 13*l.* per ton; ship plates, 10*l.* 5*s.* per ton; sections, 10*l.* per ton, and sheets, $\frac{3}{16}$ in. to $\frac{1}{4}$ in., 12*l.* 10*s.* per ton, all delivered Glasgow stations.

Malleable Iron Trade.—The position in the West of Scotland malleable iron trade has not changed and the demand is extremely poor. In the steel re-rolling branches a falling-off in business has also to be noted. Prices are unaltered, with "Crown" bars called 12*l.* 10*s.* per ton delivered at Glasgow stations. The export side of the trade is also very quiet despite the fact that one or two lots have recently been secured.

Scottish Pig-Iron Trade.—In the Scottish pig-iron trade a dull tone continues to prevail and the demand is not heavy. There is little business passing either for hematite iron or foundry grades. Prices are easier inclined although hematite is steady at 5*l.* 17*s.* 6*d.* per ton delivered at the steel works, but foundry sorts are half a crown lower, at 5*l.* 12*s.* 6*d.* per ton for No. 1 and 5*l.* 7*s.* 6*d.* per ton for No. 3, both on trucks at makers' yards. For export lots producers are quoting easier terms according to tonnage and delivery required.

Scottish Pig-Iron Shipments.—The shipments of Scottish pig-iron from Glasgow Harbour for the week ending last Saturday, June 30, amounted to 871 tons. Of the total, 741 tons went overseas and 130 tons went coastwise. For the corresponding week last year the figures were 157 tons foreign and 112 tons coastwise, making a total shipment of 269 tons.

Scottish Shipbuilding.—It is many years since the Scottish shipbuilding industry was at such a low ebb as it is at present, and no matter what improvement takes place the output of new tonnage must continue on a very low basis for many months to come. With the boilermakers' dispute still unsettled the prospects are far from bright, and new contracts being given out are very few in number. During the past month less than half a dozen have been reported: three for the Clyde, one for the Forth, and one for the Tay. The output figures for the past month were 15 vessels of 11,412 tons, made up as follows, and the totals for the past six months are added:—

	June, 1923.		Six Months, 1923.	
	Vessels.	Tons.	Vessels.	Tons.
The Clyde	13	8,512	58	145,657
The Forth	—	—	9	7,965
The Tay	1	1,600	4	21,070
The Dee and Moray Firth	1	1,300	4	3,490
	15	11,412	75	178,182

The Clyde total for the month is about the lowest output for a very long time, while the figure for the six months is the poorest first half-year total for fifteen years.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—For the first time since the national wage agreement was brought into operation the financial results of the South Wales coal trade in March and April combined were sufficient to enable the owners to pay the men the minimum wage of 28 per cent. above the 1915 standard rates without a sacrifice of their profits. The joint audit of the coal owners' and miners' accountants, after allowing for the cost of standard wages, other costs, and the owners' standard profits of 17 per cent., shows that the surplus available was 1,390,479*l.*, compared with 854,608*l.* under the audit for January and February. As a result of the audit the percentage of wages payable in July and August is 37·62 per cent. on the 1915 rates, or 9·62 per cent. above the minimum. The proceeds per ton at the pit-head in March and April were 1*s.* 9*d.* higher than those for January and February, but the costs of production were 8½*d.* higher, of which labour costs were increased by 4½*d.* and other costs by 4*d.* This increased cost was attributable to diminished outputs caused by holidays and strikes. Outputs were reduced by about 780,000 tons, of which 200,000 tons were estimated to be due to non-unionist stoppages and 580,000 tons to holidays. It may be of interest to point out that since the national agreement came into force the coal owners, in order to pay the minimum wage, have been compelled to sacrifice no less than 3,410,000*l.* of their profits, and that none of this sum is recoverable in the future. In March and April last the actual wages cost of the coal produced amounted to 4,817,000*l.*, or 1,561,000*l.* more than would have been paid for the same quantity of coal in 1913, and during July and August the cost for a similar quantity will reach 5,145,000*l.* in consequence of the advance which takes place in wages. Though there has of late been a reduction in coal prices there are prospects of a further advance in wages in September and October, for it is expected that the audit for May and June will show even better results than that of March and April.

Dischargers on Strike.—Discharging men employed in unloading pit-wood, pit props, iron ore and general cargo have been out on strike at Cardiff and Barry since Monday as a protest against a reduction of 1*s.* per day in their minimum wage, as a result of a 10 point fall in the cost of living index figure. The men contend that the cost of living has not fallen by 10 points, and on this ground refuse to abide by the Shaw agreement.

Canadian Cattle at Cardiff.—The steamer, Canadian Leader, on Monday landed 210 head of Canadian cattle at Cardiff. This is the first consignment brought direct to the port for sixteen years. On Tuesday, 112 of the beasts were sold in the sale ring of the Great Western Railway cattle lairs, and the first beast auctioned realised by successive sales 570*l.* for the Cardiff Royal Infirmary. The animal was presented to the infirmary for this purpose by the importers—the Canadian British Corporation, Limited.

CHARACTERISTICS OF FLUXING LIMESTONE.—Fluxing limestone is usually prepared in sizes ranging from 2 in. to 7 in., states Dr. Oliver Bowles, mineral technologist of the United States Bureau of Mines, Department of the Interior. Open-hearth steel furnaces usually demand stone not less than 4 in. or 5 in. in size, but for blast furnaces smaller stone may be used. Smelting companies that operate their own fluxing quarries may use stone as small as ¾ in. mixed in with the larger sizes, but where purchases are made from independent producers it is unlikely that sizes smaller than 2 in. would be acceptable. Thus 2-in. to 4-in. stone might be sold to blast furnaces in limited quantities, though a large amount of the small-sized stone would be undesirable when not mixed with the larger sizes. This use is limited not only by the demand but by transportation, for it is too low-priced to justify a heavy haulage charge. Most limestone used for lime manufacture is well adapted chemically for fluxing uses, and a number of lime companies sell fluxing stone.

TURBINES FOR JAPANESE NAVY.—The Uraga Dock Company, of Japan, have placed with the Vickers' Group, through Messrs. Vickers, Limited, Barrow, as main contractors, an order for the turbine propelling machinery required for a large destroyer they are building for the Japanese Navy. The turbine, twin screw, 39 000 s.h.p., will be of the well-known Metropolitan-Vickers design. For some time the Japanese Navy have been interested in the design and special features of the Metropolitan-Vickers impulse turbine, and but for this the order might never have come to this country as turbines of the Brown-Curtis or Parsons type would probably have been built in Japan. The turbine rotors and diaphragms will be manufactured at the Metropolitan-Vickers Electrical Company's Trafford Park Works; Messrs. Vickers, Limited, Barrow, with their large experience in naval shipbuilding, are supplying the turbine casings and the gears. This is a practical illustration of the advantages an association of companies such as comprised in the Vickers' Group possesses, when competing in the world's markets.

SHUNTING AND 'SIDING RENT CHARGES ON PRIVATE OWNERS' WAGONS STOPPED FOR REPAIRS.—The existing charges made by the railway companies for shunting and siding rent on wagons stopped for repairs are 1*s.* per wagon for shunting in and out in relation to each stoppage; 6*d.* per day per wagon (after the free period of three days) for siding rent from the date of stoppage until release. As a result of negotiations with the railway companies, the general managers have agreed, as an experimental arrangement for twelve months, to accept a commuted charge of 1*s.* per wagon per annum on the total number of wagons owned by each trader in lieu of the present charges for shunting and siding rent on wagons stopped for repairs, providing that an assurance is obtained from the Wagon Owners and Trade Associations that this arrangement will be applied to at least 90 per cent. of the privately-owned wagons (including colliery wagons) running on the companies' lines. Private owners wishing to come into the scheme should at once notify their assent, and give the total number of wagons owned by them to the following: (*a*) If they belong to any of the Wagon, or Traders' Associations, to the secretary of such association; (*b*) if they do not belong to any such associations, then to Mr. Edwin A. Hart, Secretary, Standing Joint Committee, 11 and 12, Coal Exchange, London, E.C. 3.

EXHIBITS AT THE ROYAL AGRICULTURAL SHOW, NEWCASTLE.

(*For Description, see Page* 13.)

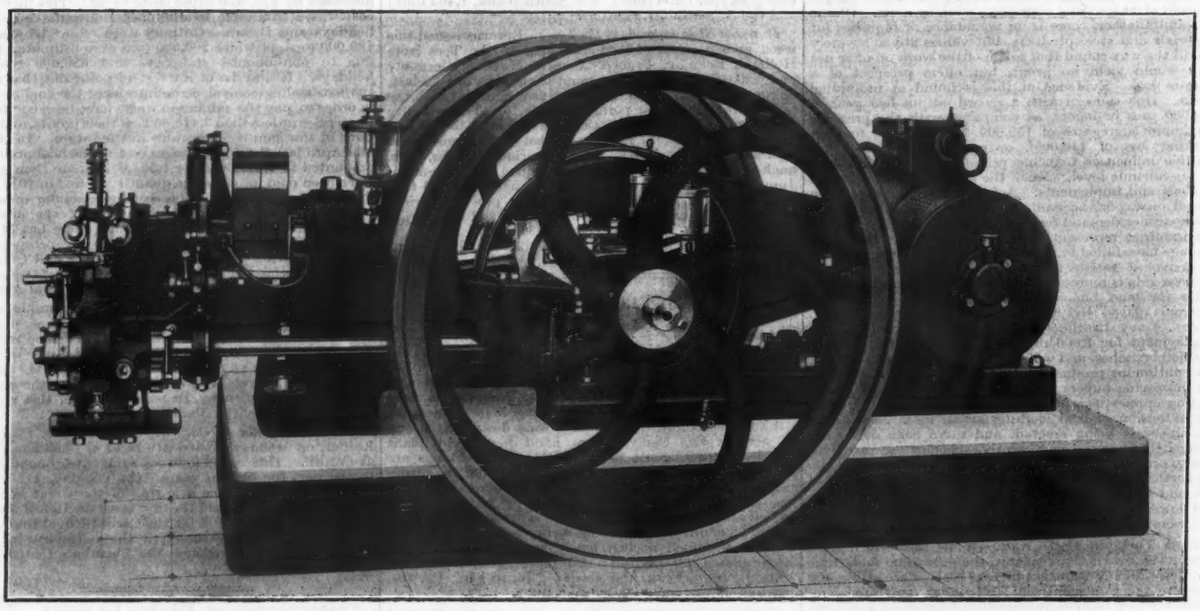


FIG. 6. 2-KILOWATT ELECTRIC LIGHTING SET; THE NATIONAL GAS ENGINE COMPANY, LTD., ASHTON-UNDER-LYNE.

SHELL DEFECTS IN STRIP STEEL.—The result of an analysis of data on open-hearth practice resulting in shelly strip steel, made by F. B. Foley, metallurgist of the Department of the Interior, at the Mississippi Valley experiment station of the United States Bureau of Mines, Rolla, Mo., showed that heats which produce shells are shorter heats, that they take more ore, and less spar, and that they give a lighter ladle skull than those that produce metal free from shells. The indication is that shells are the result of running the heat in the open hearth too hot and bringing down the carbon too fast by oreing. The metal is thus apparently over-oxidised.

THE ROYAL INSTITUTE OF BRITISH ARCHITECTS.—The newly-elected Council of the Royal Institute of British Architects has just come into office. The president, who succeeds Mr. Paul Waterhouse, is Mr. J. Alfred Gotch, F.S.A., of Kettering. Mr. Gotch, who is well known for his publications on the subject of Renaissance architecture in England, is the first non-London architect who has ever occupied the chair of the Royal Institute of British Architects, and the new council contains an unprecedented number of provincial members. Manchester (two), Glasgow (two), Bristol (two), Sunderland, Northampton, Durham, Leeds, Dundee, York, Aberdeen, Cardiff, Liverpool, Reading and Birmingham are all represented. Sir Edwin L. Lutyens, R.A., Sir John Burnet, A.R.A., Mr. G. Gilbert Scott, R.A., Sir Edwin Cooper, Mr. W. Curtis Green, A.R.A., Mr. E. Guy Dawber, Sir Banister Fletcher and Sir A. Brumwell Thomas, and many other architects of distinction have been elected to the new governing body.

MOTOR CAR FUEL.—Changes in petroleum refining practice during the past few years have been so rapid, says the United States Bureau of Mines, that automobile engineers have experienced great difficulty in designing automobile engines adapted to use most efficiently the changing grades of motor fuel placed on the market. The greater part—probably at least 80 per cent.—of all the petrol produced in America is used in motor cars, trucks, and tractors. Changes in motor petrol can often be compensated for by corresponding changes in the design of motor cars, but the designer of motor equipment is necessarily handicapped unless he knows how rapidly the fuel is changing. It has been common practice in the past to design a motor car to use efficiently the motor petrol available at the time. Experimental cars were then built and tested, and eventually the new model was placed on the market, but so rapid have been the changes in refining practice during the last few years that it has frequently happened that the character of motor petrol had radically changed by the time the new car was actually in the hands of the public. The Bureau of Mines has kept careful records for several years of the actual production and consumption of motor petrol and other petroleum products, but these statistics alone are not enough to portray clearly the petrol situation at any one time. Not only the total amount of petrol available, or the total production and consumption, but the characteristics of this fuel must be known. In order to ascertain any changes in quantity the Bureau decided to make frequent surveys of the motor fuel sold throughout the United States, and surveys of this nature are now being made semi-annually in 10 selected cities in widely separated localities. The results of the motor petrol surveys made by the bureau in 1920 and 1921, giving information regarding the characteristics of fuels sold in representative cities in those years, are given in Technical Paper 328, copies of which may be obtained from the Department of the Interior, Bureau of Mines, Washington, D.C.

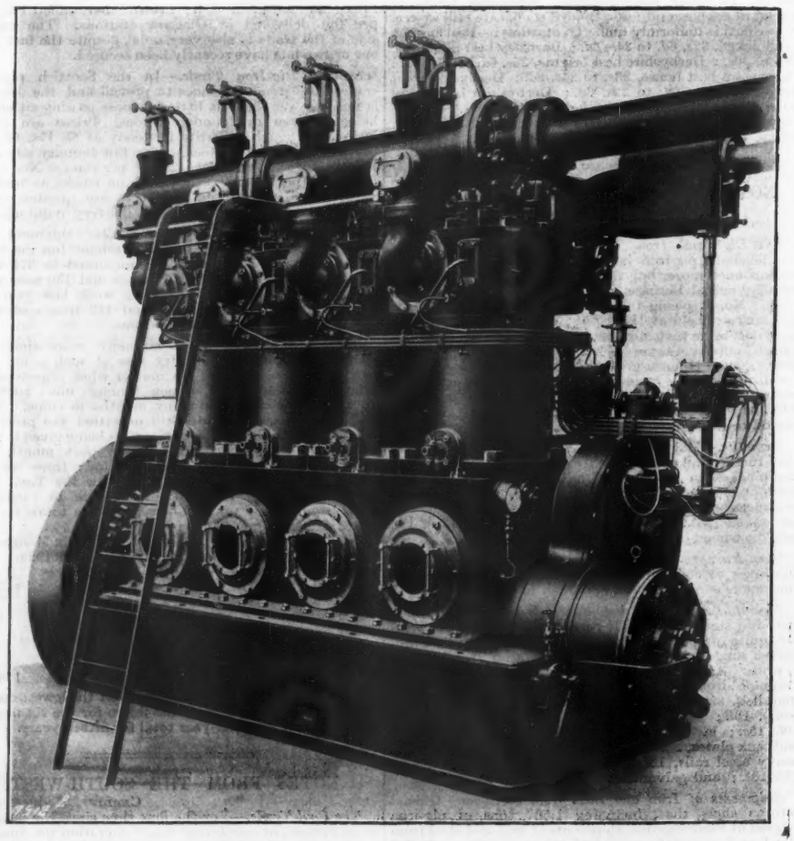


FIG. 7. FOUR-CYLINDER 180-H.P. VERTICAL GAS ENGINE; THE NATIONAL GAS ENGINE COMPANY, LTD., ASHTON-UNDER-LYNE.

4-8-2-TYPE PASSENGER LOCOMOTIVE FOR THE DENVER AND RIO GRANDE WESTERN RAILROAD.

CONSTRUCTED BY THE AMERICAN LOCOMOTIVE COMPANY AT THEIR BROOKS WORKS, DUNKIRK, N.Y., U.S.A.

(For Description, see Page 26.)

Fig. 3. Fig. 4.

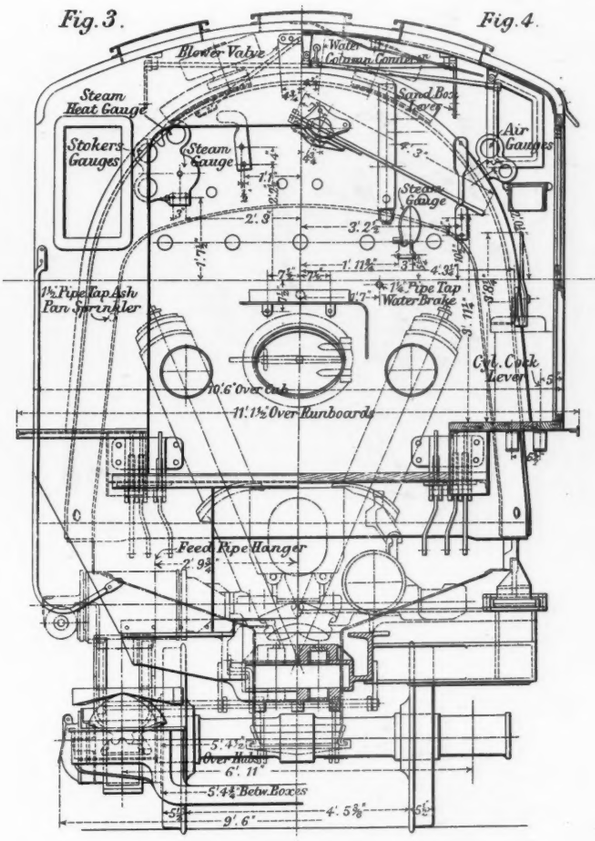


Fig. 5. Fig. 6.

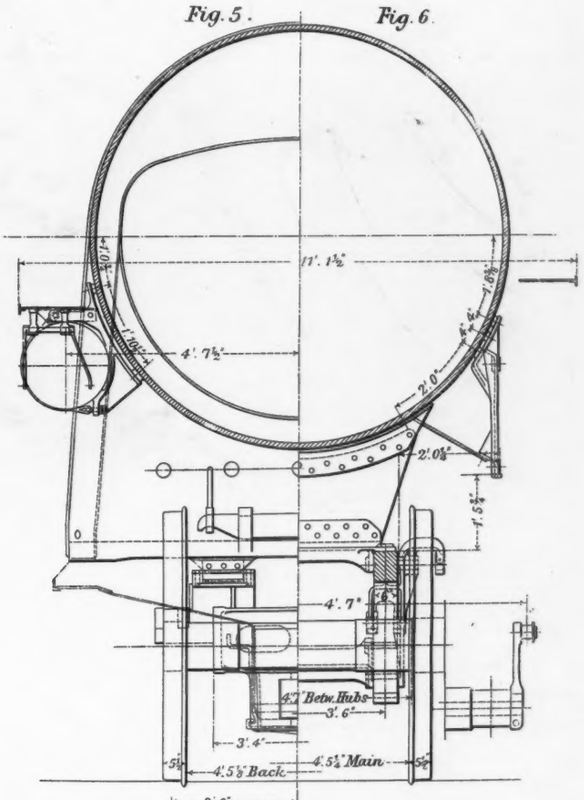


Fig. 7. Fig. 8.

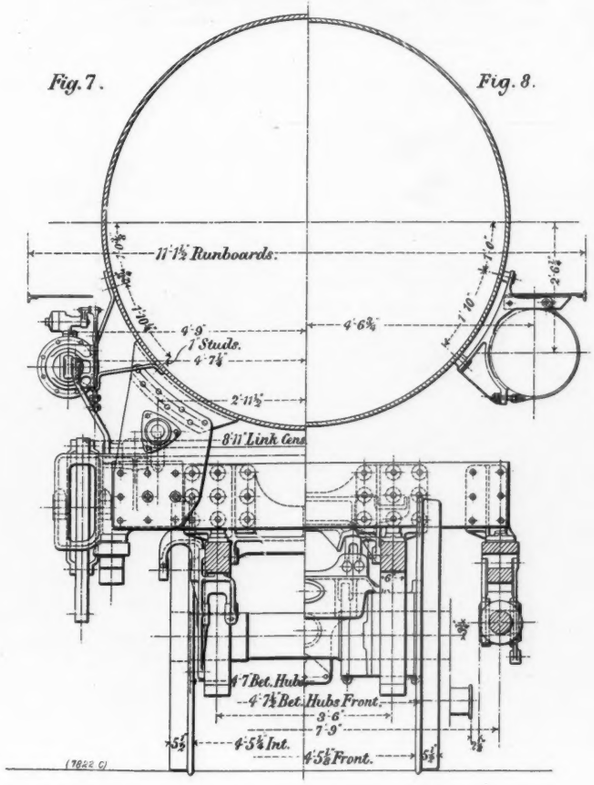
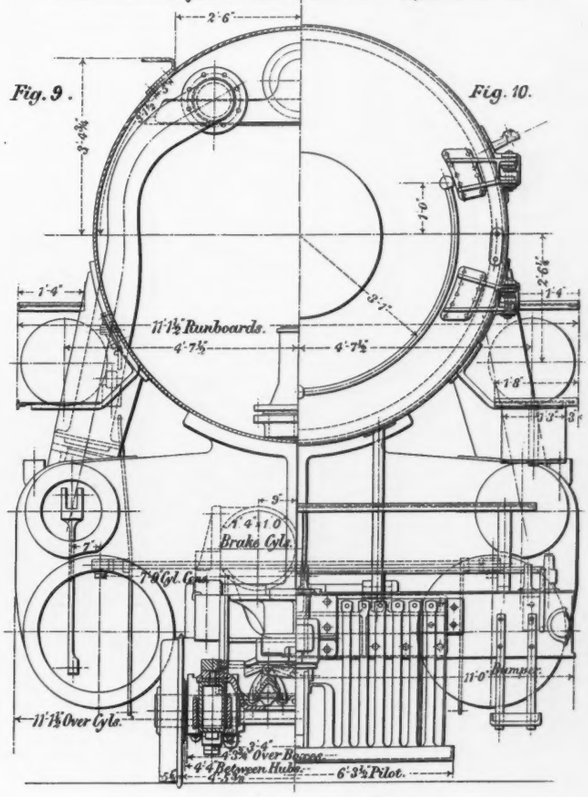


Fig. 9. Fig. 10.



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4-8-2-TYPE PASSENGER LOCOMOTIVE FOR THE DENVE

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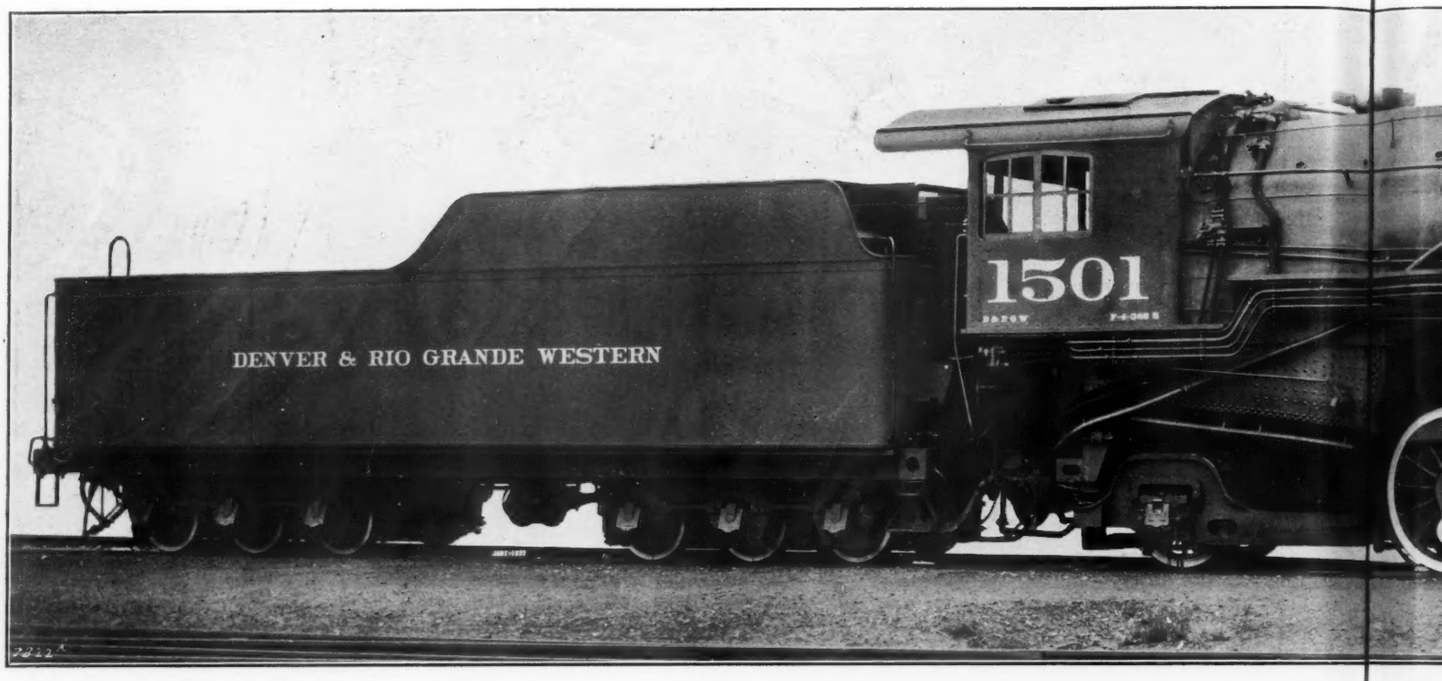

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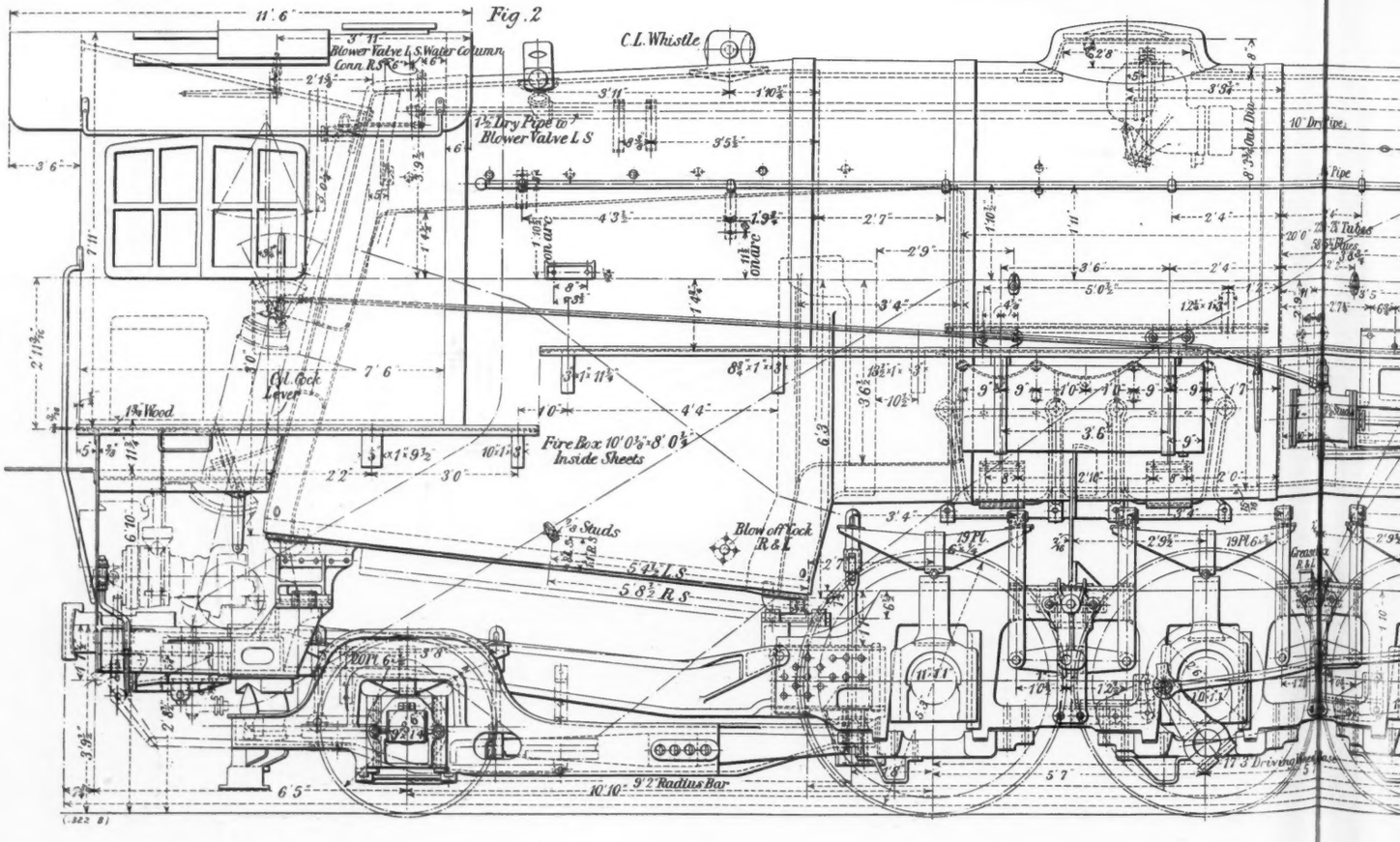


E DENVER AND RIO GRANDE WESTERN RAILROAD.

COMPANY AT THEIR BROOKS WORKS, DUNKIRK, N.Y., U.S.A.

Description see Page 26.)

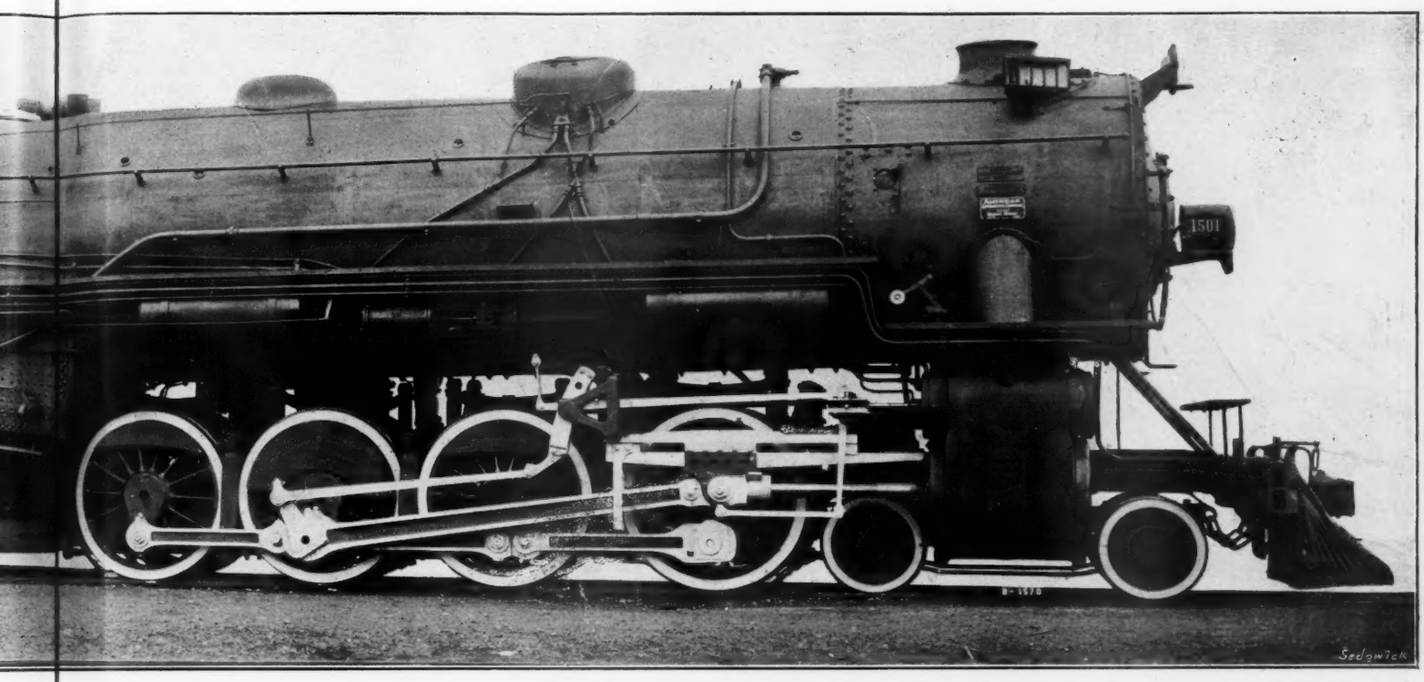
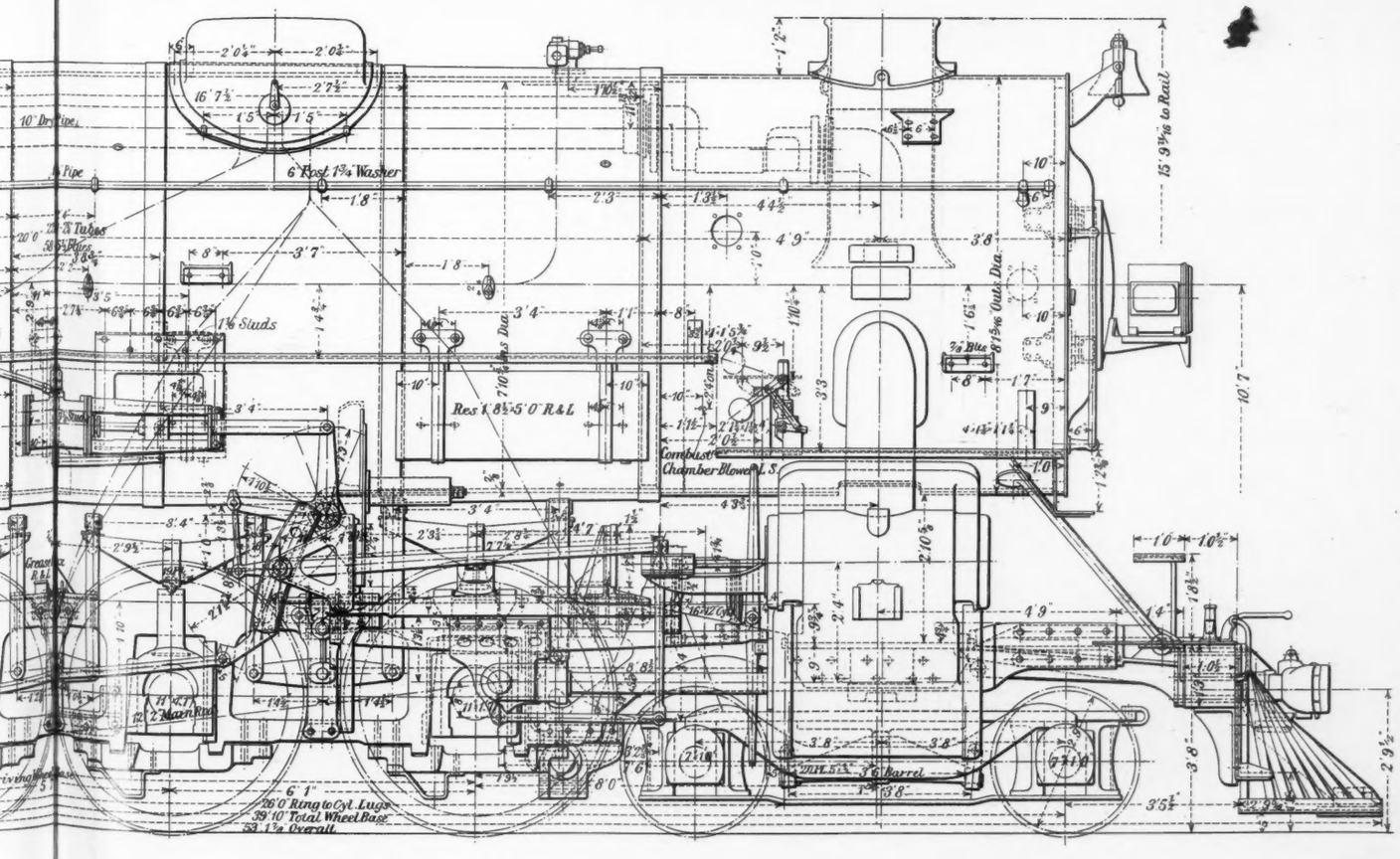


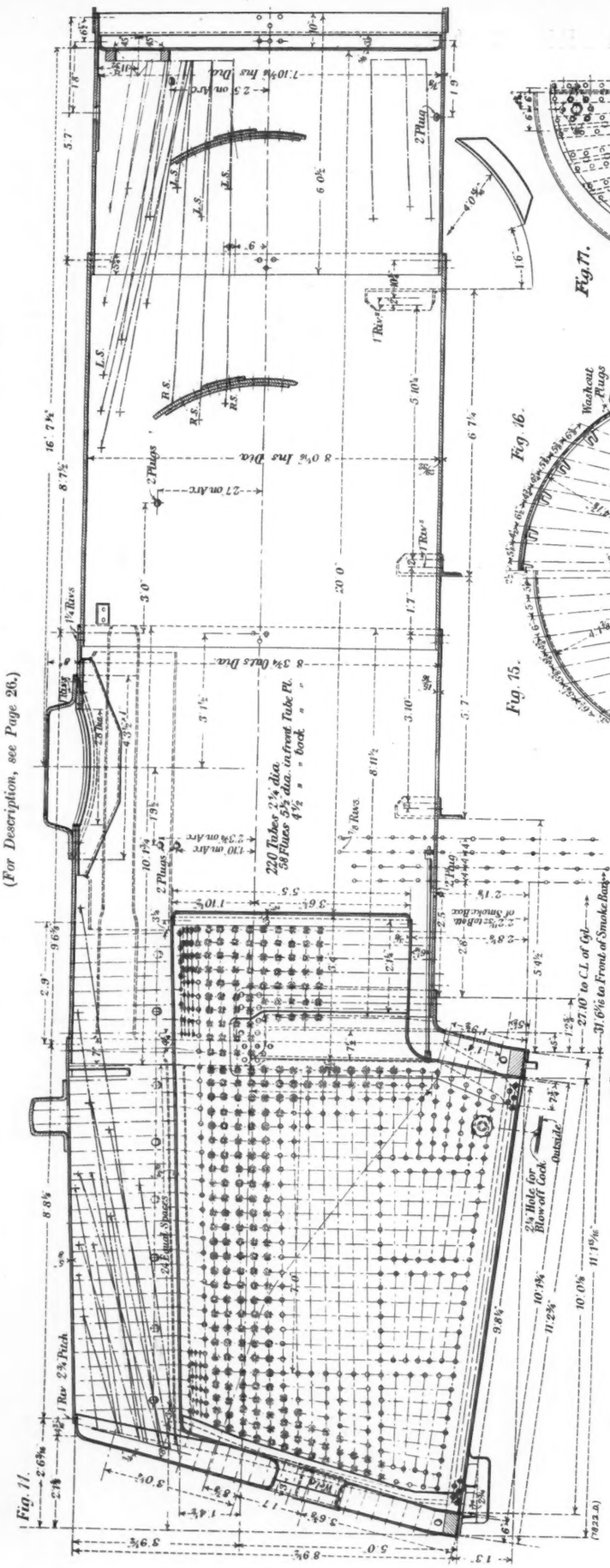
Fig. 1.

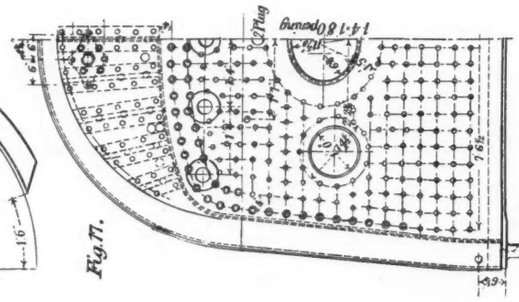


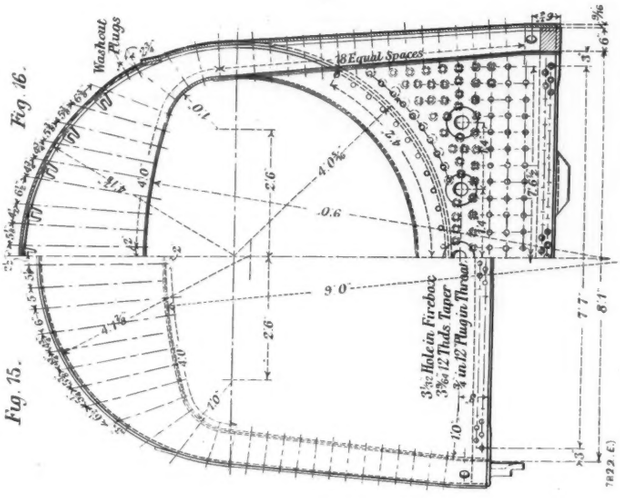
BOILER FOR 4-8-2-TYPE PASSENGER LOCOMOTIVE; DENVER AND RIO GRANDE WESTERN RAILROAD.

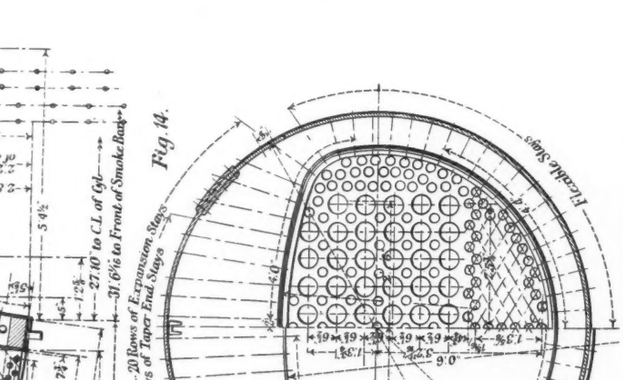
CONSTRUCTED BY THE AMERICAN LOCOMOTIVE COMPANY AT THEIR BROOKS WORKS, DUNKIRK, N.Y., U.S.A.

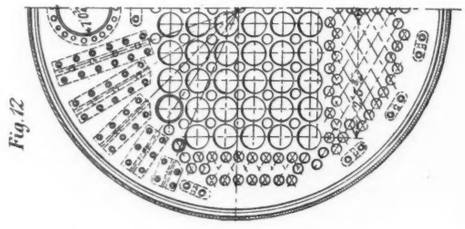
(For Description, see Page 26.)











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ENGINEERING.

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ENGINEERING.

FRIDAY, JULY 6, 1923.

THE NEW HYDRAULICS.

LECTURING a few years since at the Royal Institution, the late Lord Rayleigh quoted some exasperated experimentalist to the effect that the mathematical theory of hydro-mechanics had no relationship to the behaviour of real fluids. So long as laboratory work was confined to studying the flow of fluids through pipes or other channels the discord between calculation and observation continued, and fluids in motion did not appear to comport themselves in any particular as did the perfect fluid of the mathematician. Some slight advance was made when mathematicians learnt how to take viscosity into account, and in capillary passages our actual imperfect fluids do consent to be amenable to calculation. Osborne Reynolds was accordingly able to found a mathematical theory of lubrication, which has not only led to the development of the Michell thrust block and bearings, but has also thrown a good deal of light on the stresses to which the teeth are subjected in high speed reduction gearing.

For all practical purposes, however, the motion of a fluid in capillary passages may be regarded as at most two dimensional. Thus in a round capillary tube, the motion of the fluid is wholly parallel to the axis of the tube, whilst in a bearing there is only a negligible motion of the fluid perpendicular to the boundaries between which it is confined.

In large pipes and passages, on the other hand, the motion is commonly turbulent, and we get then any amount of cross-flow. The whole body of the tube is filled with innumerable fragments of vortex lines, the *debris* of vortices which have torn themselves to pieces by mutual interaction between themselves and their "reflexions" in the walls of the tube. As the fragment of a vortex line is wholly unstable the mathematician is helpless, and since hydraulic engineers have in the main to concern themselves with the flow of fluids through channels, our engineering colleges and laboratories have been more and more disposed to neglect hydrodynamic theory and to confine themselves to courses on practical hydraulics, with the result that their men may graduate without even hearing of Eulers' equations of fluid flow. It is not surprising, therefore, that when confronted with the new problems which the advance of "aeronautics" have brought into prominence, the "practical hydraulician" has proved a broken reed, and has been unable to frame any intelligible theory as to connection between the lift and drag of an aeroplane and the air currents developed around it.

It is now very many years since Mr. Lanchester drew attention to the inadequacy of the explanation of the lift which attributed it merely to a change in the momentum communicated to the air encountered by the plane in its flight. No doubt so far as the plane itself is concerned this explanation is correct. All the plane can "know" is that it is bombarded by air molecules of which it changes the momentum, and the lift is due to the fact that, on the whole, in these encounters more momentum is generated in a downward than in an upward direction. The momentum thus generated must, however, be ultimately cancelled by the surface of the earth, so that the momentum of the air as a whole is unaffected by the passage of an aeroplane. In the case of a ship propelled by a paddle wheel one can see very plainly the sternward momentum communicated by the floats to the water. The wake from these floats is traceable for a considerable distance ; and in the case of an aeroplane there must be some similar downward wake due to the downward momentum communicated to the air molecules which have impinged on the lower face of the wings. How far does this wake extend ? The answer appears to be that as a definite wake it extends to a very short distance indeed, and that speaking generally the motion of the air at a distance from all solid surfaces is that of the perfect fluid of the mathematician in a state of irrotational motion.

Of course we do occasionally see "smoke rings" in air, far away from any solid surface, and wherever a "smoke ring" exists the motion is not wholly irrotational, but even this rotation is entirely confined to the vortex line, which constitutes the core of the ring, the body of the fluid, although it is circulating round this line, being in irrotational motion. Rankine's free circular vortex is the type most familiar to engineers, but it appears to be far from generally realised that outside of the axis every particle moves round without rotating, just as if it were the planet wheel of a sun and planet motion, and were mounted on a connecting rod of infinite length. Conversely, in the viscous flow of a fluid through a pipe, few appear to realise that every particle is rotating about some axis. In this connection attention may be called to a curious paradox. We know that it is impossible to set in rotation the molecules of the gas argon, and it may be asked what would happen if argon were discharged through a capillary tube. Argon has a coefficient of viscosity just the same as any other gas, and according to hydro-dynamic theory the particles must rotate when in viscous flow. On the other hand the ratio of the specific heats shows that the argon molecule cannot acquire a spin. We do not know how Nature solves the difficulty, but she is proverbially feminine, and when convenient is probably prepared to dodge her own rules as unblushingly as any woman. Perhaps, indeed, she would declare that the rules were not hers, but man-made laws by which she would refuse to be bound with all the resolution of a suffragette on an arson campaign.

Taking it as established, by direct experiment, that at some very short distance from an aeroplane, no definite wake is perceptible, let us conceive a rectangular boundary containing the areoplane in its centre. The weight of the plane must be supported either by the average pressure on the lower face of the above boundary being greater than the average pressure on the top face, or by downward momentum communicated to the air which passes through the boundary, or thirdly, what actually is the case, by a combination of the two. In short, it appears that half the weight of the plane is supported by the reaction due to a downward momentum imparted to the air, but the latter does not flow down in a definite wake, but the stream lines representing the downward motion diffuse rapidly as the distance from the aeroplane increases, so that the downward velocity becomes very small when the distance from the aeroplane is great. The remainder of the weight is supported by a difference of pressure as stated, and the question arises as to how this pressure difference is produced. Lanchester gave the answer many years back that it was due to "a circulation" imposed on the fluid. This most original concept

was entirely neglected in this country, but was taken up by Prandtl in Germany, and by him and his associates has been most ably developed, so that the theory promises to become of real utility in practical aeroplane design.

When a perfect fluid is in irrotational motion its velocity at any point can be deduced in just the same way as the flow of heat in an infinite solid can be from the temperature distribution. The flow of heat in any direction is proportional to the temperature gradient in that direction. This makes it possible to simplify complex problems by treating them as arising from a combination of simpler ones. Thus if the temperature at any point is due to the combined action of two sources of heat, the flow of heat in the neighbourhood of the point can be found by considering the effect of each source separately and adding the results.

In the case of irrotational fluid motion, temperature in the heat problem is replaced by "velocity potential," and as indicated above two such potentials can be merely added together and the velocity in any direction is then proportional to the gradient in that direction of the velocity potential. Thus, if we add together a uniform flow in one direction and a Rankine vortex, the velocity due to the latter will at one point be subtracted from the uniform flow; whilst at another point it will be added to it. But by Bernoulli's principle an increase of velocity involves a diminution of pressure, and thus if a "circulation" is produced round an aeroplane by the development of vortices by the surface friction, the air pressure along a stream line above an aeroplane may be less than that along a stream line taken below the aeroplane. This has been proved experimentally to be the case, and the necessary difference between the pressures in the upper and lower faces of the imaginary boundary referred to above is thus accounted for.

The "circulation" originates, as stated, in the surface friction of the wings. In their neighbourhood vortex lines are generated, and round every vortex line there is a circulation though the particles which thus circulate do not rotate on an axis. By a further extension of the theory, a relation between the relative efficiency of a plane and its aspect ratio has been established, which appears in good accord with actual observation.

One of the most remarkable developments of the theory is the fact that having worked out the stream lines and pressure distribution round a simple cylinder, it is possible to deduce from these the stream lines and pressures round actual wing forms. This possibility depends upon certain applications of the "imaginaries" which have at times been the subject of absurd denunciations by teachers of "practical mathematics." In "All Sorts and Conditions of Men" Walter Besant introduced a character who was the best mathematician in his State "up to quadratic equations" and in reading diatribes of the above character one is led to suspect that the mathematical attainments of those responsible for them do not greatly exceed the same limit.

ALKALI WORKS IN 1922.

THE fifty-ninth annual report for 1922 of H.M. Chief Inspector under the Alkali Act of 1906, Dr. T. Lewis Bailey, records a distinct improvement in some sections of the heavy chemical trade, though not yet a re-establishment of normal conditions. The numbers of both the works registered, 1,240, and of the processes, 2,005, were smaller than last year, by 43 and 64 respectively. The inspectors had no serious difficulty in enforcing restriction of gas and dust escapes to the legal limits, and penalties do not appear to have been inflicted in any case; but steady pressure had to be applied in several instances, and it is strange that six works should have carried out registrable operations without previous registration. Saltcake, we notice, continues to be made, but the employment of gas firing with salt-cake furnaces shows no progress. Rotary grates have given encouraging results in cement works; to stop the cement dust the report recommends filter bags.

In smelting works gas-cooling is found to facilitate the dust deposition. The high percentage of lead in the blende concentrates to be smelted causes trouble in various respects, while in the mechanical calciners and in the Glover towers the volatilised lead compounds collect and form obstructions. The acidity of the sulphurous gases from smelters is still high occasionally.

As regards the electrostatic treatment of dusts and mists the report suggests that more attention should be paid to individual conditions, to humidity and to the nature of the condensed products; this applies also to the deposition of dust from burner gas where volatility and electric conductivity of the constituents cause difficulties which are not easily met. But complaints as to faulty scrubber design, inefficient tower space in scrubbers and excessive fan speeds should no longer arise.

Nor is it edifying, as the report states, in these days of scientific control to reflect on the somewhat haphazard methods prevailing in many ammonium sulphate works. The amounts of lime used for the liberation of ammonia and the heat consumption of some stills are excessive, and the whole subject of the treatment of ammoniacal liquors seems to be worthy of more attention than it receives by manufacturers. Special attention is drawn to the disposal of gas-works effluent which cannot economically be purified by chemical means such as thiocyanate and thiosulphate. In most gas works and coke oven works the volume of effluent liquor is not measured, which makes the control of the reactions difficult.

Attempts to deal with the effluent liquor from the ammonia still by bacterial action (infusion of cow dung, *e.g.*) on special filter beds fed with an effluent, from which the bulk of the phenols have previously been removed by scrubbers, have however met with success, and this treatment is to be further investigated by Mr. Linder, Dr. Bailey's assistant, and the Hornsey Gas Works. As regards scrubbing, we should mention that the use of high-pressure water sprays, in the place of the old shower and drip method, has proved advantageous in chemical manure works.

A promising novelty in tar distillation is the use of a fused lead alloy for heat transference in the still; the tar is fed in below the surface of the alloy, which is maintained at the proper temperature. Among the advantages claimed for the process is the prevention of the separation of carbon. Mr. J. W. Young, the Inspector for Scotland, reports the quite unusual occurrence of fluorine in the gas liquor of the coke ovens of the Plean Colliery Company; this fluorine, which would corrode the pipes, is removed before recovering the dissolved ammonia. The brevity of the report, due to economical considerations, is to be regretted.

THE INTERNATIONAL NAVIGATION CONGRESS.

ON Monday, the 2nd inst., the Delegates and Members of the Thirteenth International Congress of Navigation assembled at the Institution of Civil Engineers, Westminster, to attend the opening ceremony of the Congress. H.R.H. the Duke of York welcomed the delegates on behalf of His Majesty, the Patron of the Congress. In the course of his remarks the Prince emphasised the importance of such a Conference to every nation. Navigation, whether on the sea or inland, vitally concerned every country, the goods of exchange being carried so largely by sea. Moreover, it was an advantage that individuals from different countries should have such opportunities of making acquaintance with each other. He assured the delegates that they were most welcome visitors, and trusted that they would enjoy their stay.

The Right Hon. Lord Desborough, President of the Congress, then expressed the thanks of the Congress to the Duke of York, and was supported in this by M. Helleputte, President of the Permanent International Commission of the Association of Navigation Congresses. Lord Desborough next proceeded to deliver his address, and pointed out that the previous Navigation Congress held in this country took place in 1890. Since then the following congresses have been held:—1892, Paris; 1894, The Hague; 1898, Brussels; 1900, Paris; 1902, Düsseldorf; 1905, Milan; 1908, St. Petersburg; and, in 1912, Philadelphia. His lordship commented upon the many advantages of such congresses and the broad effects of unifying knowledge obtained in various parts of the world by bringing together engineers of experience in such matters as canal and river works, piers, &c. By way of instance he pointed to the discussions at the Vienna Congress in 1886, which served as a basis for investigating the question of the cross-section to be adopted for the canals of Central Europe. He hoped that the results of the 1923 Congress would be no less valuable than those of its precursors, while on certain subjects previously discussed ripened experience might lead to more definite conclusions.

M. Helleputte, President of the Association Internationale Permanente des Congrès de Navigation, returned thanks to the King, the Duke of York, and the several persons of eminence concerned with the promotion and welfare of the meeting. He felt it specially pleasurable and appropriate that, for the first time since the war, members could link up the chain of traditions in the capital of the British Empire in Great Britain, so essentially a shipping country. He hoped that the work of the present Congress would prove useful to all the nations represented by the Association; above all, to Great Britain.

Dr. W. H. Maw, President of the Institution of Civil Engineers, extended to the members of the Congress a hearty welcome from that Institution. The Congress, attended by men of the highest distinction in their several professions, would have under its notice a number of questions of the greatest national importance, more or less intimately associated with the work of engineers. It was, therefore, fitting that the Council and members of the Institution he represented should do everything possible to assist in the carrying out of the programme of the Congress. He wished the members every success in their deliberations, and trusted they would carry away some pleasant memories of their visit to the Institution of Civil Engineers.

Colonel J. C. Oakes, of the United States, expressed the sincere appreciation of his country for the invitation to take part in the proceedings. The problems in a country so large as the States were, naturally, very great, and he looked forward with much interest to the discussions which should arise on the papers to be presented. M. Mahieu, the Official Delegate of France, also spoke, and was followed by Signor Sanjust di Teulada, officially representing Italy; by M. H. Wortman, the Delegate from Holland, and by Senhor F. C. Burlamaqui, Official Delegate of Brazil.

The proceedings of the Congress were divided under two sections, the first dealing with Inland Navigation and the second with Ocean Navigation, the chairman of the first section being Lord Desborough and of the second Sir Ernest Glover. In each section various questions and communications were the subject of a series of reports from various countries, these reports being summarised and the general conclusions, if any, which might be deduced from them being given in a general report. There was thus one general report and anything up to fifteen or sixteen other reports on each question. The procedure at the meetings was in general to read the general report and discuss its conclusions, but discussion of any point brought up in any individual report was in no way excluded. There was a total of over eighty reports in all, many of them bulky, and in general we shall be unable to refer to all their details.

THE UTILIZATION OF WATERWAYS FOR THE PRODUCTION OF POWER.

The first question dealt with by the Inland Navigation Section was "The Utilization of Waterways for the Production of Power: its consequences and Applications." The general reporter on this question was Sir John P. Griffith, while reports were submitted from the United States, France, Great Britain, Italy, Sweden and Czecho-Slovakia. In his general report Sir John Griffith briefly reviewed the various detail reports and pointed out that in almost all cases the importance of this question of the production of power from waterway had come to the fore in consequence of the rising

costs of fuel. We need not reproduce his summaries of the reports as we deal with them individually below, but one of the conclusions which he submitted to the Congress we may quote in full as it deals with a point which has evidently been the subject of much consideration in many countries. The conclusion is "that it is desirable to have state control of the water resources of the country; and to establish an authority to allocate water for the various interests, with a service whose duty it should be to investigate proposed schemes and formulate a policy for utilizing in the best interests of the community the water resources of the country." It will be evident that this conclusion bears on questions of navigation and riparian and fishery rights as well as power development, and it is in virtue of the former of these that the question comes within the scope of the Congress of Navigation. The whole of the matters concerned are however so closely bound together that the question can only be considered as a whole.

In addition to his summaries, Sir John Griffith took advantage of the rules of the Congress to add some personal views and information to his general report. This information referred to Ireland, a country of which Sir John has long personal experience. Since 1880, five commissions of various kinds had inquired into the question of inland navigation in Ireland, and the findings of all of them pointed to the necessity of some form of unity of control. The matter was followed up after the war when the shortage of coal caused anxiety, and in 1918 a sub-committee for Ireland was appointed in connection with the Water Power Resources Committee. Irish imports of coal represent 57 per cent. of the fuel requirements of the country, and the findings of the sub-committee were to the effect that 500,000 water horse-power is continuously available in the country. Under its constitution the Irish Free State claims the ownership of all natural sources of water power and a question has been submitted for the consideration of Congress. An interesting case for possible development in Ireland is furnished by the River Shannon which has a catchment area of over 4,000 square miles or about one eighth of the total area of Ireland. The length of its main stream is 160 miles, excluding the tidal estuary below Limerick. The flow ranges between very wide limits varying from 42,000 cub. ft. a minute to 1,947,000 cub. ft. a minute. The river has been under continuous observation since the middle of the eighteenth century. In 1915, Mr. Theodore Stevens surveyed the power possibilities of the river for the Irish Hydro-Electric Syndicate, and produced a scheme calculated to furnish an average of 17,000 h.p. throughout the year and 40,000 h.p. for 20 weeks. It was proposed to use the power for the manufacture of ferro-chrome.

The United States report was prepared by Colonel William Kelly, Chief Engineer of the Federal Power Commission, and the most important part of his report was probably that referring to the activities of the Federal Power Commission which was created by the Federal Water Power Act of 1920. This Commission gives the unity of control, the necessity for which has become apparent in so many countries. It has had imposed on it the duty of granting licences for power developments that affect navigable streams on public lands, and is charged with the duty of determining that any proposed power development is in accord with the best scheme of development from the point of view of public interest. It imposes any necessary conditions for the protection or improvement of navigation. The Commission has established a rule that where navigation exists the licensee must make provision for preserving it, and where there is no navigation he is required to so design his works as to provide for future navigation facilities. When navigation works are constructed by the Government in such a way that power is made available the Federal Power Commission is authorised to grant licenses for the use of the power by private parties.

Colonel Kelly gave some details of the work which has been done in connection with the Tennessee, Mississippi, Ohio and Columbia rivers, but space does not permit us to reproduce them. We may, however, quote some of the information he gave in reference to the important case of the St. Lawrence. The river rises in Lake Ontario and discharges into the Atlantic through the Gulf of St. Lawrence. Its total drainage area is 309,500 square miles, including the Great Lakes, and has an average flow of 241,000 cubic feet a second. In the stretch between Lake Ontario and St. Regis, a distance of 112 miles, and where the river forms the international boundary between Canada and the United States, there is a fall of 92·5 ft., of which 48 ft. are concentrated at Long Sault Rapids. In the 70 miles from St. Regis to Montreal there is a further fall of 129 ft. Montreal, 1,000 miles from the sea, is the head of ocean navigation, and below that place the channel has been improved by Canada to have a least depth of 30 ft. and a least width of 450 ft. Above Montreal the Canadian Government has constructed six side canals, with 23 locks, to provide navigation round the principal rapids. The power developments on the St. Lawrence at present have a total installed capacity of 313,450 horse-power. In the international section 9,400 horse-power is on the Canadian side and 86,600 horse-power on the United States side. Below the international section, in Canada, there is 217,450 horse-power, and of this some 60,000 horse-power is electrically transmitted to the United States.

In 1920 the Governments concerned instructed an International Joint Commission to investigate the question of the improvement of the St. Lawrence between Montreal and Lake Ontario. The Commission reported in 1922 to the effect that potential traffic probably existed which would justify such improvement in the river, and that for many years to come the benefit of anything which was done would be much larger in the case of the United States than of Canada. Existing means of communication in the United States area affected are now inadequate, but the same remark does not apply to the Canadian side. It was stated that although the improvement of the entire reach was feasible, the loss of power which can be generated as a by-product in some reaches would not be warranted. The development of the 4,100,000 potential horse-power of the river could, however, be made co-ordinate parts of schemes for the improvement of navigation. The report also expressed the view that the power of the entire river could not be marketed in a reasonable time, and it is suggested that the international section alone should at first be developed. Several applications have been made to the Federal Power Commission for power developments on the international section, but the Commission is withholding action until some agreement is reached with Canada as to the manner of carrying out the entire development.

The French report was by M. L. Armand, Inspecteur-Général des Ponts et Chaussées, Paris. It referred to the importance which now attached to water power development and the facility with which the power could be transported by electrical means, incidentally quoting an interesting early water power scheme which was carried out in 1871 in the Department of the Ain at a fall known as the Perte du Rhone. The available fall was 14 metres and some 8,500 horse-power was available. It is not stated what proportion of this was developed, but the interesting feature is that the power was transmitted mechanically by ropes for a distance of 1 kilom. The installation apparently operated for at least 35 years. M. Armand's report was mainly devoted to a consideration in general terms of river canalisation from the combined points of view of navigation and power production. He dwelt on the special difficulty from the latter point of view of the frequent cases of low falls of variable head which canalisation led to. He then dealt with various actual cases, referring in some detail to the much-discussed canalisation of the French Rhone. The river may be divided into three natural sections, of which the first, from the Swiss frontier to Château du Parc, is at present unfit for navigation owing to rapids. Two schemes are proposed for dealing with this section, one involving two weirs and the other one only, giving a single fall of about 70 metres. The second section, to the confluence of the Saône at Lyons, has low banks and a large number of small weirs would be necessary if much cultivated land were not to be submerged. The third section is only suitable for power production as far as the confluence of the Gardon, owing to the very slight slope of the land beyond that river. On the whole, some 500,000 kw. of power are estimated to be derivable from the river. The output would be fairly constant throughout the year, owing to the low and high-water periods affecting the different sections differently.

M. Armand also dealt with the proposed canalisation of the Rhine between Basle and Strasbourg, which is being put forward to the International Rhine Commission by the French Government. The scheme provides for a single weir 5½ kiloms. from the frontier and the diversion of some 10,000 to 15,000 million gallons of water a day to a lateral canal on the Alsace bank of the river. The canal would have a total length of about 70 miles and would be divided into eight sections by means of locks, the falls at the locks varying from 33 ft. to 42 ft. Hydro-electric stations would be erected at the canals, and it is estimated that a total of 567,500 kw. of electric power would be rendered available.

Three reports were presented from Great Britain. The first of these was by Mr. W. J. E. Binnie, and dealt in the first place with power production from artificial canals. Confining consideration to this country, Mr. Binnie said the power available at the average lock of the average English canal was about 90 h.p., but that in some special cases where there were flights of locks, as, for example, on the Leeds and Liverpool Canal near Wigan, where the head was 200 ft., this power might amount to 3,000 h.p. This power could, however, not be developed without abundant water supply, and the actual conditions were such that the provision of such supplies was not economically possible. Canalised rivers offered a more hopeful field, and considering the Thames from Sandford Lock, just below Oxford, to the Old Windsor Lock, on which length there were 24 locks, with a total fall of 130 ft., Mr. Binnie estimated that about 12,700 h.p. might be developed. He thought there was a *prima facie* case for detailed investigation. A consideration of the canalised part of the Severn between Stourbridge and Gloucester suggested that there might similarly be some 9,000 h.p. available in connection with it.

The power development of the tidal part of the Severn was dealt with in a special report by Messrs. C. S. Meik, G. L. Addenbrooke and J. W. Twinberrow. This proposal has received a good deal of attention, and its main lines will be generally known. The scheme dealt with is that for a barrage at Beachley Head, which is some 8 miles above Avonmouth, and the tidal conditions which have been worked out are based on a valuable report made for the Gloucester and Berkeley Canal Company in 1850 by Captain Beechley, F.R.S. The survey made by Captain Beechley did not extend quite to the proposed site of the barrage, and it is pointed out in the report that the exact locating and other details require further investigation. It is stated that the construction of the barrage would improve navigation and make a large area available for industrial development. The road and railway across the estuary which would be carried by the barrage would be of great value from a transport point of view. The road would greatly improve access to South Wales, while the railway would meet a necessity which is already being felt by the Great Western Railway, and which may be met in the future by a further tunnel or a bridge if the barrage is not built.

These various advantages would be quite independent of any question of the generation of electric power which was put forward as the main argument in favour of the barrage when the famous account of it was published by the Ministry of Transport. Briefly the power generation schemes proposes variable head turbines which at times when full power was available would pump water up to storage reservoirs which would be some 700 ft. above Ordnance Datum. The plant would be of sufficient capacity to maintain the normal outside load in addition to carrying out this pumping, while at times of little or no head, this impounded high-level water would be utilized for power generation. The report points out that the turbines would work under conditions very similar to those at the great Keokuk barrage on the Mississippi. This plant is designed for 30 turbines and 15 have so far been installed. They run at a constant speed of 58 r.p.m. at all heads, each giving 14,000 h.p. at

39 ft., 10,000 h.p. at 32 ft., and 6,000 h.p. at 20 ft. For the Severn barrage the Oerlikon Company and Messrs. Escher Wyss offered to construct turbines running at a constant speed of 60 r.p.m. over a range of heads varying from 29 ft. to 9 ft. That is a range of 3·2 to 1 compared with the range of 2 to 1 of the Keokuk plant. The machines would be rated to give 6,000 h.p. at 29 ft. head, 3,300 h.p. at 20 ft. head, and 1,000 h.p. at 9 ft. head. They would be coupled to three-phase generators. It is estimated that 200 such machines would be necessary to develop the full 1,200,000 h.p. which would be available at spring tides. The cost of the generating plant is estimated at 8,000,000*l.* and the barrage at 10,000,000*l.*

The third report presented from Great Britain was by Mr. R. F. Hindmarsh and consisted of a general consideration of the question of power production from tidal and non-tidal rivers. In connection with tidal schemes it was pointed out that as the time of high tide varies around the coast some interconnection scheme giving fairly uniform power production might be worked out. High water at Flamborough is for instance 12 hours later and in the Thames 19 hours later than in the Scilly Isles.

The report from Italy was presented by M. Annibale Pallucchini. It dealt in an able way with the dual requirements of navigation and power production on canals. The combination of power production with proper navigating facilities on canals is in many cases not an easy problem, and M. Pallucchini stated that on some of the canals in the Venetian plain, power consumers are obliged to close the intake to their power plants on one or two days a week in order to maintain a proper water level for navigation. This is no doubt essential in the particular circumstances, but is hardly a satisfactory arrangement.

If any considerable amount of water is taken from an industrial canal for power production it is clear that the effect will be to increase the speed of the current, the assumption, of course, being made that the water is available. This raises the interesting question of the allowable speed of the current in such canals. If the current is too rapid it demands excessive tractive force up stream, while coming down stream it may make pilotage difficult, and may lead to accidents when boats are passing. It also increases mooring difficulties. In that part of the Suez Canal where the current is affected by the Red Sea tides there is a regulation that when the current exceeds 0·9 metre a second and ships are passing, the vessel moving up stream must moor in one of the relief basins and allow the other to pass. M. Pallucchini concluded that on canals serving both for navigation and the production of power, the maximum speed of the current should not exceed 0·5 to 0·8 metre a second. The smaller the water section of the canal the lower the allowable maximum speed.

The report from Sweden was compiled by M. Sven E. Lubeck and M. Axel Exwall. It discussed the problem from the Swedish point of view and was in the main concerned with a description of Swedish conditions. The authors pointed out that from the particular point of view in question the country could be divided in four sections. The most northerly one extending from the Arctic Circle to the neighbourhood of Stockholm, and comprising the whole Norrland, was distinguished by rivers flowing into the Baltic mostly rather rapid and broken up by rapids. The rivers are used for log transport and their power development must be arranged not to adversely affect this important trade. This area contains 4·9 million h.p. of which 0·55 million has been developed. The second section extending to the latitude of Gothenburg and forming middle Sweden contains Sweden's great lake system and embodies important canals. There is, however, much water power available in the rivers flowing to the great lakes. The h.p. in this area is estimated at 0·9 million and so far 0·55 million has been developed. The third section comprises the Smaland highlands and is again distinguished by rapidly flowing rivers with falls. The area is estimated to contain 0·4 million h.p. of which half has so far been developed. The fourth section comprises southern Sweden and is almost entirely agricultural containing no water power of any importance. It is estimated that the country as a whole contains 6·2 million potential h.p.

The last report on this question comes from Czecho-Slovakia and has been compiled by Messrs. J. Smetana, A. Pacak and J. Till. It deals with problems connected with the proposed power utilisation of water which is discharged through a diversion canal at the mouth of the River Moldava where it enters the River Elbe in the centre of Bohemia. We have not space to reproduce the discussions bearing on this particular problem, but the communication may be looked upon as a contribution to the general question, at it contains many tables and curves showing the effect of the speed of the current on the power required for towing and the transport of sand and other material by the water of the canal.

The discussion on this question was taken at the afternoon meeting on Monday, the 2nd inst., and the morning meeting on Tuesday, the 3rd inst. The question of the effect of the damming of rivers on land drainage was raised by Mr. Sidney Preston. Such damming was frequently undertaken for power purposes without the effect on drainage being properly considered, and much trouble has been experienced by the Ouse Drainage Board owing to old power rights. Colonel Saner said that he had gone into the question of power supply from the River Weaver many years ago and found that there was little in the proposal owing to the variable flow and the stand-by steam stations which would be necessary. M. Muller, one of the representatives of Czecho-Slovakia, said that the important effects of current speed on erosion and power required for transport had been but little examined, and much work was still required in connection with them. Various other speakers dealt with one or other aspects of the matter, Mr. G. J. Griffiths, engineer to the Thames Conservancy Board, expressing the opinion that damming if properly regulated need not interfere with land drainage. Objection was taken to the wording of some of the conclusions, especially by some of the speakers from foreign countries, and finally a small committee was appointed to revise these conclusions. The revised conclusions were put to the meeting on Tuesday morning and accepted unanimously. It is not necessary that we should reproduce them in full. The important resolution was to the effect that it is desirable that the water resources of a country as they affect water supply, irrigation, fisheries, power supply and drainage should be under the control of a single authority. A further conclusion was that all technical research work likely to throw light on the problems to be dealt with by such a body should be encouraged.

Accommodation at Ports and the Size of Ships.

The first question to be dealt with by the Second Section of the Congress which was concerned with Ocean Navigation was "The Accommodation to be Provided for Ships in connection with the Construction of New Works at Ports in order to Satisfy the Future Dimensions of Ships." The general reporter on this question was Mr. L. H. Savile, Civil Engineer-in-Chief to the Admiralty. Mr. Savile's report was most excellently done, and we shall quote largely from his summaries of the detailed reports in dealing with them. He divided the various reports into groups, pointing out that five dealt with the dimensions of ships, eight with the accommodation to be provided for ships, and six were concerned with descriptions of new works. Some reports came under more than one head. In the first group the conclusions come to and which were put forward for consideration by the Congress were (1) that, although the total number of ships in the world of 1,000 tons and upward has remained nearly constant in recent years, there is and will continue to be an increase in the average tonnage, more especially in ships of from 5,000 to 8,000 tons, but that it is unlikely that there will be any great increase on the size of the largest pre-war ships in the near future. (2) That vessels of 1,000 tons and under still number about 50 per cent. of the total and will for an indefinite time have to be reckoned with in the consideration of port requirements. (3) That there is a tendency, for economic reasons, for a general increase in the draught of large ships. (4) That the percentage number of vessels of 30 ft. draught and over is at present very small, but is on the increase, and that there is little doubt that, when the Suez Canal is deepened to 40 ft., the percentage number above 30 ft. will greatly increase, and that first-class ports should have approach channels not greatly inferior to the Suez Canal. The same remark applies to ports served by the Panama Canal, which already has a depth of 40 ft. (5) It is generally agreed that the cost of freight decreases as the size of the ship increases.

The conclusions reached from the second group were:—(1) That the present depth in harbours and approach channels sets a check on increased draught, and it is doubtful if this is sufficiently allowed for in some of the reports. (2) That the difficulties of finding full cargoes and the enormous terminal sheds involved is setting a check on abnormally large cargo carriers, and that, apart from passenger ships, there is no probability of the trade of the world being carried only in ships of large dimensions. (3) That the claim on economic grounds for increased draught in passenger and passenger-cargo ships should be examined on the basis of total outlay on ships and harbours. (4) That adequate railway accommodation and cargo-handling appliances are of no less importance than berthing accommodation. (5) A first-class passenger harbour serving the Atlantic trade should provide depths in the neighbourhood of 40 ft. L.W.O.S.T. (6) A first-class harbour serving the largest cargo-passenger ships should provide 35 ft. L.W.O.S.T., at a few tidal berths with the possibility of deepening these to 40 ft. in the future. (7) That there is a consensus of opinion in favour of width from cope of wharf to shed of 35 ft. to 40 ft.

The conclusions from the third group were:—(1) That the reports submitted show that, where provision is made, or about to be made, for a draught of 40 ft. for Atlantic liners, that the provision for cargo vessels is of a much more modest nature. (2) That the estimated cost of a harbour or harbours suitable for a given draught of vessel varies approximately as the cube of the draught. (3) That as the trade of a port is largely carried on by moderately-sized ships, the harbour dues obtained from ships of extreme draught is quite inadequate to pay for the cost of the extra works needed to accommodate them. As a general conclusion, Mr. Savile pointed out that the lack of co-ordination between shipbuilders and shipowners and dock authorities in the past has been a serious defect in port development, and suggested that a permanent committee, representing all the various interests, would be of value.

As 18 reports in addition to Mr. Savile's general report were presented on this question, we cannot pretend to deal with the majority of them in any detail. Some, however, contained figures or other data of interest which may be quoted. We will take them in the order in which they are numbered. The first was from Belgium and was compiled by M. L. Bonnet, Ingénieur-en-Chef Directeur des Ponts et Chaussées, of Antwerp, and M. F. Urbain, Hydrographe Principal, Antwerp. They gave figures for maximum sizes of ships in 1850, 1914 and the present time as follows:—

	Length.	Beam.	Draught.
	Ft.	Ft.	Ft.
Maximum size in 1850	279	41	16½
Atlantic liners, 1914	919	98	38
Maximum size in 1923	1,000	102	35

The points which they considered of special importance in meeting the increased size of ships are quay walls, maritime locks and entrance channels, and they indicated that in Belgium quay walls are built for a fixed depth of water. They then gave details of the new Kruisschams Lock, now in course of construction at Antwerp. This has two rolling gates and may be made either 738 ft. or 886 ft. long. The width of entrance is 115 ft. and the depth at entrance 33 ft. O.L.W.

The next report was received late and was not dealt with by Mr. Savile. It was by Captain H. Von Heidenstam, and is a description of the development of Shanghai Harbour. The depth of water at present is 24 ft., but it is proposed to increase this so that a

ship of 33 ft. draught can enter at neap tides. The report from Denmark, by M. G. Lorenz, Chief Engineer of the Port of Copenhagen, was concerned with a general description of the extensions and improvements which have been made in the port since 1891. The United States report was compiled by Captain F. T. Chambers, Consulting Engineer on Port Facilities to the U.S. Board of Engineers. The report stated that the increase in size of ships during the last 50 years has been so great as to give extravagant ideas about future increases. Ships of the following tonnages appeared about the years mentioned :—

Year.	Tonnage.
1864	1,000
1864–68...	2,000
1879	4,000
1889	7,600
1914	56,000

Since 1890 the proportion which vessels of 5,000 tons and over built yearly bears to the total number built was constantly increasing. The greatest increase had been in ships of 5,000, 6,000 and 8,000 tons, in the order named. Out of 14,513 steamships listed in Lloyd's Register, 1918–19, only 0·68 per cent. were over 30 ft. draught. Since increased cargo capacity meant increased earning capacity, there must be a good reason for this limitation in size. It lay in the limitations of harbours. There were 48 ports which could be entered by ships drawing 40 ft., and 59 in addition usable by vessels of 35 ft. draught. Nature had placed a limit on the practicable increase in draught of ships. The report from France was by M. G. Clavel. He reviewed the question of port capacity and steamer size in general terms, and suggested that in the cases of ports, up-river ports of call should be established near the mouth of the estuary, thus shortening the time of travel of passengers by eliminating the delay due to passage up the river.

Great Britain was represented by no less than 10 reports which together covered the whole ground in a very complete way. Sir Cyril Kirkpatrick, Engineer-in-chief of the Port of London Authority, expressed the opinion that entrance locks intended to accommodate the largest steamers should be not less than 1,100 ft. long, 130 ft. wide and 45 ft. deep, and that in due course vessels 1,100 ft. long will be constructed. A width of 150 ft. for transit sheds and 40 ft. for quay space was suggested as being the most economical and suitable. Mr. Savile, in addition to acting as general reporter, had furnished a special report on the cost of constructing harbours to accommodate vessels of the largest draught. He gave estimates of the cost of constructing harbours in silt, clay and in silt and clay overlaying rock and of various depths. The calculations indicated that increase in cost was approximately proportional to the ratios of the cubes of the draught. It was further deduced that if by the introduction of ships of a deeper and consequently more economic draught the saving on cargo carrying was one shilling a ton, the deepening of a harbour to accommodate such ship could not be justified unless the annual tonnage to the port exceeded by more than 60 per cent. the cost in pounds sterling of deepening the harbour. The next report was by Mr. F. E. Wentworth Shields, Engineer of the London and South Western Railway Docks at Southampton. The report described the arrangements and accommodation at Southampton, and expressed the opinion that in designing new docks berths of 1,000 ft. long should be provided. In designing dry dock entrances it was suggested that only one or two feet in width and one foot over the sill need be allowed over the beam and draught of the vessels to be dealt with. In this connection it was stated that the Berengaria of 98½ ft. beam has been successfully placed in the Trafalgar Dock which had an entrance 100 ft. wide.

A report by Sir John Biles treated a different phase of the question and considered the determination of the sizes of the ships in which goods may be transported over a total sea distance at the lowest transportation cost per ton-mile. This is a complicated question involving many factors, and Sir John gave a series of six diagrams in three-dimensional forms in which length of ship, rate of handling cargo and transportation costs were taken as variables. He suggested that a Chair of Shipping Economics might well be founded for the study of this and allied problems. A further valuable report was presented by Sir Westcott Abell. It formed an analysis of the composition of the British merchant fleet, and the conclusions will best be given by quoting two tables from the report :—

TABLE I.—*Percentage Numbers of Vessels of Various Sizes for Different Years.*

Gross Tonnage.	Year.			
	1901.	1907.	1912.	1922.
100 to 1,500	59	56	55	59
1,500 to 5,000	37	38	38	24
5,000 and above	4	6	7	17
	100	100	100	100

TABLE II.—*Approximate Gross Tonnage of the Various Larger Types of Steam Vessels in Millions of Tons.*

Gross Tonnage.	Year.	
	1914.	1921.
1,500 to 5,000	11,508	7,788
5,000 to 10,000	5,338	8,802
10,000 and above	1,983	2,701
Totals	18,829	19,291

A third table indicated that the smaller sizes remain in service for a much longer period than the larger ships.

Mr. J. Foster King dealt with a further phase of the same subject and was concerned with the growth in the size of ships as deduced from the experience of the past. The past rate of increment of length projected into the future indicated that the largest ships plying between New York and Europe would be 1,400 ft. long by 1942. Continuance of recent increases of draught would indicate a draught of 45 ft. by the same year.

Other reports from Great Britain were contributed by Mr. Adam Scott, Mr. T. S. Gilbert, the Engineer of the Belfast Harbour Board, Mr. V. G. Gedye and Mr. S. Alfred French. Mr. Scott thought that in the next 10 years a length of 750 ft., beam of 87 ft. and draught of 36 ft. should cover the passenger-cargo liners built, but that ports wishing to cater for the largest passenger liners and to plan 20 to 25 years ahead should build locks 1,150 ft. long, 125 ft. entrance width and 50 ft. over sill. The other authors from Great Britain discussed the question generally, but did not give any figures which we need quote. The Italian report was by Professor Luiggi. He pointed out that the modern tendency in ship construction was increase of draught rather than length, and indicated that shipowners foresaw large cargo boats of a possible maximum of 15,000 tons, with a draught of 26 ft. to 30 ft. and liners of from 25,000 to 35,000 tons with a draught of 28 ft. to 32 ft., and that Atlantic vessels of 45,000 to 60,000 tons of 35 ft. draught will be an exception. He is of opinion that channels such as the Ambrose (40 ft. deep) to New York and the Crosby to Liverpool are so costly that they will not be surpassed in this generation. A report from the Netherlands, written by Mr. D. Boomsma, Chief Engineer of Works to the Port of Rotterdam, pointed out that the average net tonnage of ships entering the largest ports in 1920 was comparatively small. He gave the following table :—

	Tons.		Tons.
Hamburg ...	733	Liverpool ...	2,972
London ...	1,154	Antwerp ...	1,198
Rotterdam	1,309	Marseilles ...	1,789

The final report on this question contributed from Sweden was written by M. P. G. Hornell. He pointed out that rivalry between large ports leading to increased facilities will tend towards larger ships. His words were :—"The fight for independence on the part of the second rank ports and for continued hegemony on the part of such gigantic ports as London and New York are the forces that will continue to add to the size of the transmarine vessel."

BERTHING ARRANGEMENTS FOR LARGE SHIPS.

The second question submitted to the Ocean Navigation Section was entitled "Types of Works for Berthing Ships of Great Draught in Tidal Seas." This question is obviously closely allied to the first and the two were discussed together. The general reporter on the question was Mr. M. F-G. Wilson, of Messrs. Coode, Fitzmaurice, Wilson and Mitchell. Mr. Wilson pointed out that the question was of a very wide character and that it was difficult to draw any general conclusions from the series of reports which were largely concerned with descriptions of works carried out or projected at different ports. The conclusions which Mr. Wilson was able to draw from the reports were embodied in 10 resolutions which were submitted to the meeting. Some of these are naturally of a very general character, such as, for example, that satisfactory means should be provided for the rapid handling of passengers and cargo, and it is not necessary that we should reproduce the whole of them. Certain resolutions we may, however, quote—one is to the effect that at least 3 ft. of water should be allowed between the bottom of a vessel and the dock bed, and another that when the range of tide exceeds 15 ft. it is preferable to provide wet docks entered through lock gates. It is also suggested that wherever possible continuous quays should be provided, but that if passengers alone were to be dealt with, or cargo only to a limited extent, continuous quays, although the more convenient, were not essential. Ample width, of the order of 50 ft., should be provided between the face of the quay and the sheds or warehouses.

Six detail reports were furnished on this question, the first coming from Belgium and being compiled by M. L. Bonnet, Directeur des Ponts et Chaussées, Antwerp, and M. A. Braeckman, Ingénieur des Ponts et Chaussées, Antwerp. It dealt with the Port of Antwerp, the shipping trade of which rose from 7,000,000 tons in 1900 to 14,000,000 tons in 1913. There are 18,000 ft. of quay space on the Schelde and 71,500 ft. in the docks, the maximum depth being 38·5 ft. This accommodation is now being extended and a large wet dock with lock entrances is being built at Kruisschans with a depth of 39·5 ft., and quay walls along the Austruweel bend with a depth of 43 ft. at low water. The average range of tide is 14 ft. 9 in. The largest vessels using the port have a draught of from 33 ft. to 35 ft., and it is not expected that a draught of 37 ft. 9 in. will be exceeded. The report dealt in some detail with the quay walls which are to be built on the Austruweel bend and gave sections of various types of wall which have been considered. The authors described these as the solid wall, the tapering wall, the wall with disconnected foundations, the wall with sunk caissons, the wall with raised foundations, and the wall in form of a wharf. The solid wall, which is illustrated in Fig. 1, on page 24, needs no description. The authors pointed out that while it was costly it lent itself to easy construction in concrete, and its solid face directed and trained the current, tending to maintain the depth in front of the wall. What they call the tapered wall is of much the same type as a solid wall, but with an inner void and a front mask to carry the superstructure forming the quay as shown in Fig. 2. The mask was the weak point in the design, and might be damaged by shock from vessels.

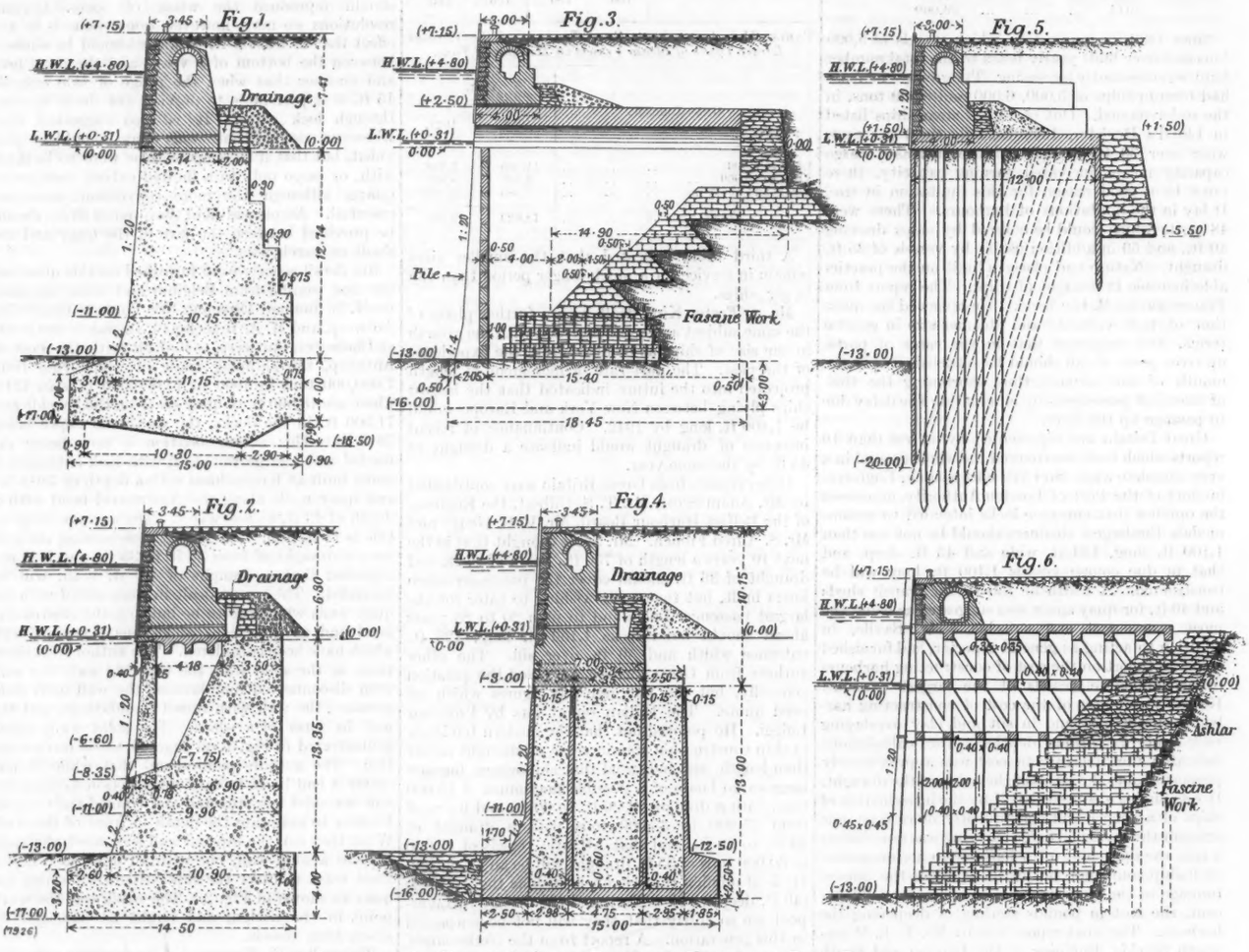
The wall with disconnected foundations consisted of a series of masonry piers placed some 30 ft. to 50 ft. apart and connected by arches or reinforced concrete slabs as shown in Fig. 3. The filling between the piers was retained in place by a facing of rubble stone or fascine work. This type offered some facilities in construction, but the great length of the piers was a disadvantage. The wall with sunk caissons consisted of reinforced concrete caissons built in the dry and towed to position and sunk as in Fig. 4. The construction offered many advantages, and the compartments between the caissons, except at the front, might economically be filled with sand or very poor concrete. Inconveniences of this system were the necessity for a large toe and great width of base and the difficulty of dredging a level bed on which to sink the caissons. In the wall with raised foundations a masonry superstructure was laid on a platform supported by piles as shown in Fig. 5. The piles might be of timber if required to carry from 25 tons to 30 tons per pile, or of reinforced concrete if required to carry from 40 tons to 50 tons. The horizontal forces were

balanced by driving a proportion of the supporting piles at an inclination. Sheet piling was necessary along the front to direct the current and avoid undermining the filling at the back, or the face of the piling below the wall might be protected by fascine work, but this is difficult to repair. The wharf wall avoided the pressure due to the filling at the back which involved solid walls being of large dimensions. With a wharf wall the ground might be allowed to take its natural slope and the superstructure carried on a wide platform supported by piles extending back to the top of the slope as shown in Fig. 6. To reduce the width of the platform the slope was faced with fascines and rough stone, but notwithstanding this a width of 65½ ft. was necessary. This width, together with the facing of the slope, made the method costly. The authors on the whole preferred the solid wall, and it has been recommended for the new Antwerp wharf, but tenderers will be free to submit alternatives.

A report from the United States was submitted by Captain F. T. Chambers. It is, however, very brief, and does not call for any quotation, Captain Chambers pointing out that this question is really part of the first question and that it does not call for independent discussion. The French report is by M. Outrey, Ingénieur des Ponts et Chaussées, Le Havre. He described various works recently carried out at Havre, Boulogne, Marseilles, Nantes and Bourdeaux, and then turned to a consideration of the requirements of the future. He considered that a maximum draught of 44·3 ft., requiring a dredged depth of 46 ft., should be provided for. He discussed quay arrangements, and for large cargo vessels considered an arrangement of heavy piers or dolphins, against which the vessel was moored. Barges and small craft could lie between the dolphins and the quay, and travelling transporter cranes connected the dolphin with the quay and sheds. Such an arrangement was suitable only for a single ship, and to accommodate a number of ships a series of dolphins should be built a distance apart equal to half the length of the shortest vessels. From this he arrived at the continuous quay wall, which he showed to be the most convenient for many purposes, particularly for cargo steamers making a considerable stay in port and requiring rapid handling of the cargo.

Reports from Great Britain were presented by Mr. M. F.-G. Wilson and Mr. A. T. Walmisley, engineer to the Dover Harbour Board. Mr. Wilson considered the case of accommodation for vessels drawing not less than 38 ft. and a maximum tidal range of 15 ft., and discussed the question of quay walls. For greater ranges of tide than 15 ft. he assumed that wet docks would be provided. He considered that an allowance of 2 ft. of water below the bottom of the vessel should be made, and assumed a level of quay 8 ft. above high water. This gave a total height of quay wall above the sea bed of 63 ft. He then discussed berthage accommodation for dealing with passengers and cargo, and, in addition, the case when sheds, warehouses and railways were required immediately adjoining the quay. Speaking generally, quays to meet the first requirement only may be of open construction, but in the latter case continuous solid construction or its equivalent must be employed. In the cases of quays carrying sheds where the cargo might be transferred by cranes direct into the sheds the space between the quay edge and the shed might be narrow, but when the cargo had to be first placed on the quay, as was usually the case, a width of not less than 50 ft. should be allowed for. The report by Mr. Walmisley discussed types of quay structure and pointed out that timber structures were easier to repair than concrete structures, concrete being less resilient and more liable to fracture. Framed structures were, generally speaking, more subject to deterioration and decay than those of solid stone or concrete. Noting that there is no accepted definition of the term "deep-water quay" the author called attention to the manner in which the dimensions of vessels have grown, and considered that the harbour engineer should anticipate vessels 1,000 ft. long, 100 ft. beam and 40 ft. draught. He incidentally pointed out that Portland cement blocks were first used in the Admiralty Pier, Dover, in 1849.

The final paper on this question was contributed by M. D. Boomsma, Chief Engineer for Port Works at Rotterdam. He described various quay walls at Rotterdam and elsewhere and passed on to the question of moorings for the middle of docks or rivers. Mooring dolphins formed of groups of piles were in general not considered sufficiently solid for ships of large dimensions, although this form of construction had recently been considerably improved by staying and binding the piles together with steel cables. Two such dolphins placed 400 ft. apart should safely hold a vessel 300 ft. long. For large vessels reinforced concrete caissons in the form of towers had recently been adopted. The caissons were floated out to site and lowered into a firm stratum of sand, the overlying soft material having first been removed by dredging. The dredged pit and the caisson were then filled in with sand.



FIGS. 1 TO 6. TYPES OF QUAY WALLS FOR VESSELS OF DEEP DRAUGHT.

The superstructure containing the mooring posts was so designed as to give way before the caisson could be overturned.

General deductions from these two main reports were embodied in two series of broad proposals. These were intentionally framed by Messrs. Savile and Wilson in such a way as to invite discussion, and their efforts were in every way successful. After the general outlook of the members had been discovered to some extent, a sub-committee was appointed to frame a series of recommendations which would be acceptable to all. Such a matter must always be difficult, but after further consideration on Wednesday, under the chairmanship of Sir Maurice Fitzmaurice in the morning and Sir Ernest Glover in the afternoon, agreement was reached, and the recommendation adopted in the form of a resolution.

After enunciating that the increase in the number of ships drawing 30 ft. and over would be limited by the facilities offered by the main canal routes and the principal harbours, and that there would be an increase in the average tonnage, more particularly in ships of from 5,000 tons to 8,000 tons, the necessity for providing accommodation solely guided by considerations of economy was emphasised. That this was necessary was evident to all who listened to the able demonstration by Mr. Savile, that the cost of dock construction varied approximately with the cube of the depth.

A statement was embodied in the resolution that facilities for rapid and economical handling and despatch of goods at ports was as important as the obtaining of a suitable depth of water. The proposal was made that it might be useful for an inland port authority to construct a port of call near the coast for ocean liners. The final parts of the resolution related to the necessity for payment to dock authorities for the deeper draught ships of proportionately higher harbour dues, and that except for the Atlantic passenger service it was difficult to justify the necessity for a depth of water at the quay side of more than 35 ft. at low water ordinary spring tides, for many years to come. The provision of 30 ft. of water under such conditions it was thought should give the port rank as one of the first class. In conclusion, it was agreed that each nation should make an exhaustive study of the subject by representatives of the various interests concerned, namely: Shipbuilders, shipowners, dock authorities and engineers and railway administrators, and that it should be an instruction to the committees to consider the establishing of systematic research into the whole question of economic draught for ships and depth of docks, as the want of co-ordination had prevented economic development in the past.

A letter from the American Association of Port Authorities to Captain Chambers, in which reference was made to the establishment of a commission on the questions discussed, was read to the meeting, and later Captain Harold, R.N., read a note on suggested changes in ships' signals in foggy weather, to enable the officers of each to know the course of the other.

(To be continued.)

INDUSTRIAL NOTES.

THE Birmingham journals report that a further reduction in the wages of workmen in the non-trading departments of the Birmingham Corporation will take place as from the first pay-day in July. The revision, which is made under the sliding scale governed by the cost of living, was reported to a meeting of the Salaries, Wages and Labour Committee, presided over by Alderman Sir David Brooks. The amount of the reduction will be 1*s.* 3½*d.* per week, thus bringing down the minimum wage to 49*s.* 6½*d.* for a general labourer. Men in occupations above the minimum will have their wages reduced proportionately. The departments affected include the public works, salvage, parks, baths, education, markets and fairs, and others, and about 4,500 men are involved. The last reduction was made in January. Adjustments are usually made at the end of three months, but the fall in the cost of living at April was not sufficient to warrant a reduction at that time.

Sir David Shackleton received at the Ministry of Labour last Saturday Mr. J. Marchbank, president of the National Union of Railwaymen, and Mr. C. T. Cramp, industrial general secretary, to discuss with them the question of the railway companies' demand for a reduction by 6*s.* 6*d.* per week of the war bonus to railway shopmen. At the end of the meeting, Mr. Cramp stated that the railway companies had approached the Ministry and expressed the view that the difficulties should be referred to the Industrial Court for arbitration. That proposal had been conveyed to them (Messrs. Marchbank and Cramp) in the morning, and they had explained to Sir David that the national delegate conference had taken the stand up to the present that the National Union of Railwaymen would neither negotiate nor agree to arbitration on the proposed reduction, which was regarded as being without justification. They informed Sir David that all the time that decision stood it was impossible to accede to the companies' request. They had, however, promised to report the decision to the annual meeting, taking place at Crewe this week, and upon the decision would depend the future course of action.

Mr. Cramp understood that the Ministry of Labour had also conferred with the craft unions, but he was unable to state what their attitude had been. The craft unions all along had refused to associate themselves with the National Union of Railwaymen in any of the negotiations regarding the shopmen's wages, and had adopted an attitude of aloofness.

It is stated that quite apart from the reduction in the war bonus of the railway shopmen, the railway companies are contemplating a revision of the working conditions and pay of the men in the traffic grades.

This question is one of those which are being considered at the Conference of the National Union of Railwaymen being held at Crewe during the present week. In the course of his presidential address to the conference, delivered on Monday, Mr. J. Marchbank said that the decision of the Industrial Court had clearly defined the position of the railway shopmen. He complained that the railway companies had placed obstacles in the way of giving full effect to the award. An important feature of that award was that shopmen were regarded as part of the *personnel* of the railway industry. Up to the present they had been successful in resisting the companies' demand for the withdrawal of the remaining war bonus of 6*s.* 6*d.* per week. Mr. Marchbank added that machinery for dealing with the conditions of men in railway shops at the moment appeared to be almost impossible. The obstacles in the way were the various craft organisations who continued to keep the men divided. He regretted that the efforts to bring about an amalgamation of the several railway trade unions had not yet met with success.

An unauthorised strike of dockers has been declared at several of the large English ports, as a protest against the reduction of 1*s.* per day under the September agreement, on the basis of the index figure for the cost of living. The National Transport and General Workers' Union, to which the men belong, has published a manifesto stating that the reduction is in accordance with the national agreement; it regrets the action of the men and advises them to return to work without delay. This the men refuse to do, and at the time of writing, the strike, fanned it is said by outside political agitators, is spreading rather than abating.

A dispute occurred a short time ago at the Hebburn Colliery following upon the miners refusing to work until a number of the deputies joined the Durham Miners' Association. The difficulty has culminated in a strike. The Council of the Durham Deputies' Mutual Aid Association held a meeting in Durham last Monday and passed a resolution stating: "That this meeting having fully considered the circumstances surrounding the dispute at Hebburn Colliery—*re* the transfer of members from Durham Miners' Association to the Durham Deputies' Mutual Aid Association, enters its protest against the action of the Durham Miners' Association in seeking to settle the matter at issue between the two associations by means of the brutal weapon of a strike, rather than by other and more conciliatory means, believing, as the meeting does, that had the Durham Miners' Association responded to the invitation of the Durham Deputies' Mutual Aid Association to discuss fully with them without bias, the matter in dispute, the present regrettable position would not have been reached, nor the consequent suffering endured by the parties concerned. This meeting expresses its appreciation of the action taken by our Executive Committee in regard to the case, together with the stand taken by the Hebburn Deputies' Lodge, and pledges the fullest support of this association, financial or otherwise, in order to bring this matter to a successful issue."

Mr. C. W. Bowerman is shortly to retire from the post of secretary to the Trades Union Congress. The official list of nominations to the post contains the names of eight candidates. The election of a successor to Mr. Bowerman, selected among the eight candidates, is to take place at the Congress at Plymouth on September 3. The annual salary of the secretary is stated to be 750*l.*, and it is proposed that he shall devote the whole of his time to the work of the Congress and General Council. Whatever may be said in regard to the Labour organisation, it cannot be asserted from the above that it is a niggardly organisation as far as the remuneration of its officials goes. There are numbers of men who would undertake the duty for the remuneration named, and many more who would undertake it for much less and do it well. The stipulation to the effect that the new secretary to be appointed shall devote his whole time to the business in hand would seem to imply that hitherto the post, although perhaps not of the kind generally denoted as "soft jobs," has been one that has not of necessity occupied the whole energy of the successful candidate.

In the ballot which is to be taken in connection with the boilermakers' strike, the question asked will be simply: "Are you in favour of continuing the dispute?" The ballot papers are to be returned on Monday next, and the usual two-thirds majority is required to settle the point one way or the other.

CORROSION OF METALS IN ACID MINE WATER.

RESULTS of the microstructural examination of more than 50 metals and alloys which had undergone corrosion from immersion in acid mine water are given in Bulletin 5, Coal-Mining Investigations, just issued by the Carnegie Institute of Technology. The work was performed at the Pittsburgh experiment station of the Bureau of Mines, Department of the Interior, in co-operation with the Carnegie Institute of Technology and an Advisory Board of coal-mine operators and engineers.

The corroded test specimens of metals and alloys examined had been immersed for periods of some months in acid mine waters for the purpose of determining the corrodibility of various materials in such waters, information of this nature being considered essential in the selection of alloys for employment in mining equipment. It was thought that microscopic examination of the various samples corroded in the previous investigation might throw light on the causes for corrosion under the particular condition involved, and that data obtained from such study might also be of value in studying the fundamentals of corrosion. Study was made of the metals and alloys in their original condition and after corrosion. It was found that in brasses, the grain size seemed to have little, if any, effect upon the rate or nature of the corrosion. There was selective corrosion in some of the bonzes and brasses.

Aluminium and aluminium alloys pitted so badly that selective corrosion could not be identified as such.

Some alloys, which after corrosion and subsequent cleaning appear to be free from adhering coating or precipitate, had a very hard and probably quite impervious coating acting as a protection; this was particularly true of the bronzes. Corrosion attack did not, in general, follow grain boundaries, but proceeded through the less resistant material if two or more phases were present.

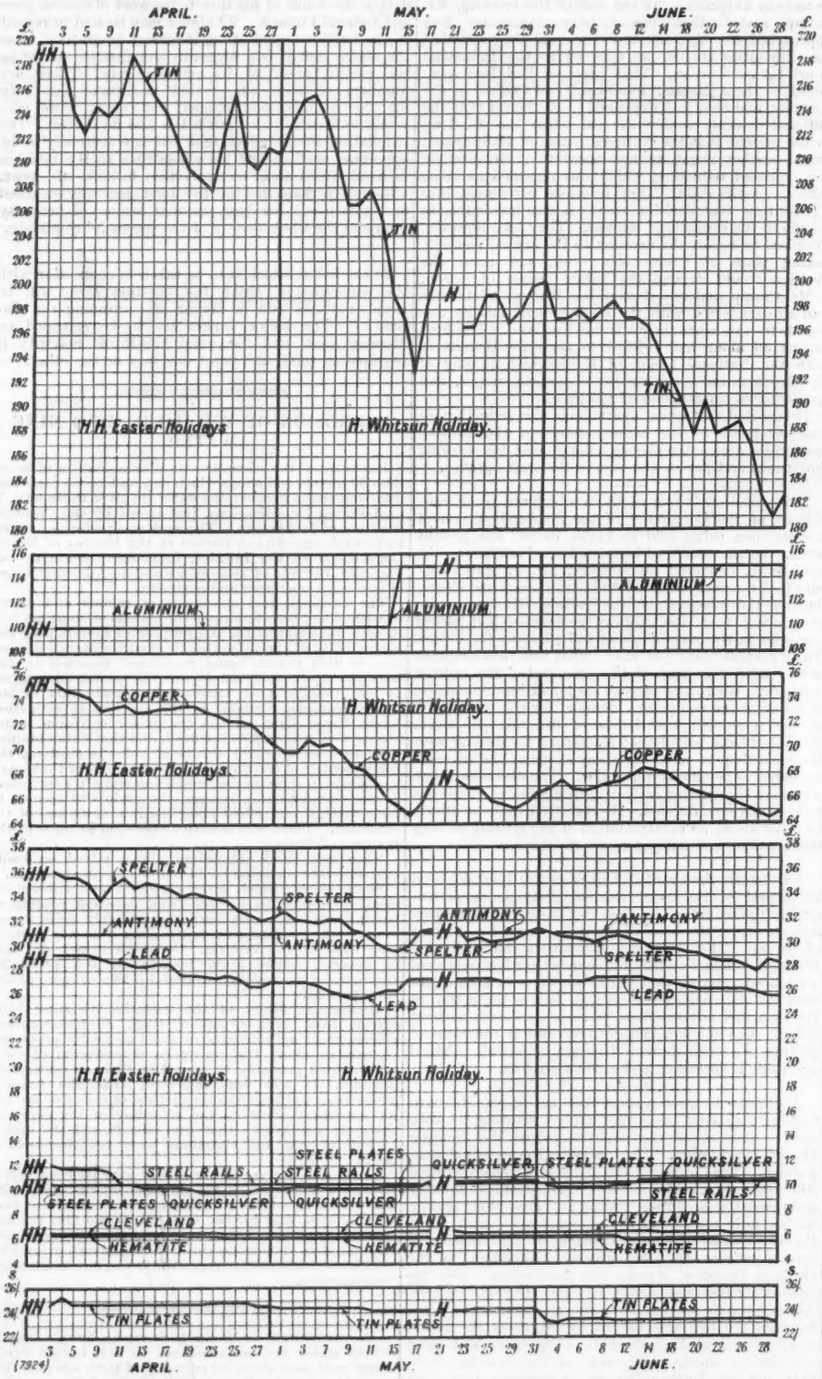
Microscopic study of the corrosion resisting high-silicon iron, high-chromium steel, chromium-nickel-silicon steels and nichrome revealed no visible protecting coating or film. The resistance to corrosion of these alloys could probably be traced to their chemical composition. It was true, however, that the physical properties resulting from the method of manufacture had an important effect on the retarding of the corrosion rate. It was known that iron silicide and the double carbide of iron and chromium were very insoluble in acids.

Study had not yet been made of very thin coatings or films, nor had study of the thicker coatings—protective and otherwise—been completed. Some data had been accumulated, and further research on the film problem was in progress. Laboratory experiments were contemplated to determine the nature and extent of films that were of ultra-microscopic thickness, but which might be protective.

MANUFACTURE OF SCHOOL SLATES.—Several million school slates are manufactured in the United States every year, and about 90 per cent. of them are exported, according to the Department of the Interior. Slate suitable for the manufacture of school slates is found in soft black beds free of all hard streaks or knots of flinty material. Such slate may be used also for roofing, but they commonly fade rapidly when exposed to the weather. They are split in the same manner as roofing slates, but the trimming is done with small saws that rotate at high speed. When trimmed to size, they are delivered to the school slate factories. Here the edges are first bevelled and then the slate is placed on edge between two knives and a descending bar forces it down so that the knives scrape off all rough projections. A second pair of knives gives the slate a smoother surface. The slates are then polished between sanded drums, thoroughly washed in hot water, and carried on a belt conveyor through a heated chamber to dry them before piling. The slates are then ready for framing. Slates broken in the framing process are unframed and re-cut to smaller sizes.

DIAGRAMS OF THREE MONTHS' FLUCTUATIONS IN PRICES OF METALS.

(Specially Compiled from Official Reports of London Metal Markets.)



NOTE.—In the diagrams the figures plotted for tin and copper are the official closing cash quotations of the London Metal Exchange for fine "foreign" and "standard" metal respectively. The prices shown for lead are for English metal, whilst those for spelter are for American metal. Middlesbrough prices are plotted for steel plates and rails, and also for hematite and Cleveland pig-iron. The prices given, in the case of steel plates are for ship, bridge and tank qualities, and those for steel rails are for heavy sections. The pig-iron prices are for the East Coast hematite and Cleveland iron, both of No. 1 quality and for home consumption. The price of tin-plates is per box of I.C. cokes f.o.b. at Welsh ports, but in all other cases the prices are per ton. Each vertical line in the diagram represents a market-day, and the horizontal lines represent 1*l.* each, except in the case of the diagram relating to tin-plates, where they represent 1*s.* each.

CONTRACTS.—The Hamworthy Engineering Company, Limited, of 76, Victoria-street, London, inform us that they have received an order from H.M. Office of Works for two air compressors, each driven by a 25-b.h.p. motor, for use in the House of Commons.

THE INSTITUTION OF MUNICIPAL AND COUNTY ENGINEERS.—The West Midland district meeting will be held at the Council House, Sutton Coldfield, at 2.30 p.m., on Saturday, July 21, when papers will be presented, and visits paid to various places of interest.

4-8-2 TYPE LOCOMOTIVE FOR THE DENVER AND RIO GRANDE WESTERN RAILROAD.

THE Denver and Rio Grande Western Railroad is a combination of two systems operating in the most mountainous section of the United States. The former companies, now reorganised into one, were the Denver and Rio Grande, and the Rio Grande Western. Although the latter system was purchased by the former many years ago, and controlled by it, it is not long since the whole has been reduced to one system under the present name. Originally planned as a north and south line to extend from Colorado to Texas, the Denver and Rio Grande ultimately developed into an east and west system threading the defiles and passes of the Rocky mountains at their most difficult point. Its early days were full of excitement, for it was on more than one occasion anticipated by a powerful rival, the Atchison Topeka and Santa Fe, and at one time actually construction parties of both railways were at work in the Royal Gorge. To anyone who is acquainted with this famous gorge the absurdity of trying to put two lines through it is manifest, but for those who are not so familiar with the grandest of all the features which gave to the Rio Grande line the name of the "Scenic Route," we may explain that at one point, at its greatest depth, the gorge is so narrow that at a rocky bend the railroad is compelled to pass above the Arkansas River with which it elsewhere shares the bottom. The line is carried on a bridge, the beams of which are built into the rock on one side and supported by a girder on the other. The girder is suspended from two steel trusses which span the gorge. The stream actually rounds the bend immediately below the track by which the railway negotiates the corner. The occupation of the gorge by parties of both railroads led to a great deal of trouble. Positions were fortified and fights, resulting in bloodshed, were common. The case took over two years to pass to the Federal Supreme Court for decision, and during practically the whole of that time the rivalry of the companies resulted in violence by organised fighting forces, the main point in dispute being the passage of the Royal Gorge. Ultimately a decision was given, as a result of which a compromise was arrived at by which the Rio Grande relinquished its proposal for a main line to the Southern and Eastern States, while the Atchison road in return abandoned its intention of carrying its system into the heart of the territory now served by the Rio Grande.

The Royal Gorge is the portal to a tract of country of very impressive character. The traveller, after hours of rolling plains, suddenly finds himself among mountain peaks and valleys, with most striking features. The country is so hilly that both systems were originally built to a gauge of 3 ft., of which part still remains.

The main system now consists of a more or less direct route from Denver southwards to Pueblo, then running practically west through Salida to Grand Junction, all in Colorado. From Grand Junction the trend is more generally north-west, the terminal being at Salt Lake City, in Utah. The section between Salida and Grand Junction is through very difficult country, the line rising over the Marshall Pass at an elevation of 10,856 ft., and passing close to such mountains as the Ouray Peak (13,955 ft.) and Mount Shavano (14,179 ft.). Of the original narrow gauge, a stretch of about 137 miles on this section remains unconverted to the present time, and this direct route is therefore only possible with a change from standard to narrow-gauge trains at Salida and Montrose. A through standard-gauge route exists, however, which, if not boasting of quite such high altitudes as those of the narrow-gauge, can claim to be fully as interesting. This line runs at first north from Salida, and then due west. Its highest point is the summit of the Tennessee Pass (10,240 ft.), and it winds its way among mountains of 14,420 ft., 14,332 ft., &c., some of them of quite exceptional beauty. Beyond the Pass the line threads the Eagle River Canyon and the Colorado River Canyon, both of which abound in interest. It is on this line that the heavy traffic of the system has to be handled. In summer the tourist traffic involves the regular operation of trains made up of 15 all-steel passenger cars, with speeds averaging about 30 miles an hour. Although there are sharp pulls between Denver and Pueblo, the worst section is between Pueblo and the Tennessee Pass and on to Minturn. On this stretch of 162 miles the line rises nearly 6,000 ft. with many lengths of 1·42 per cent. gradient. West of the Tennessee Pass the grades are as steep as 3·33 per cent., but on this section a helper is provided, in the form of a Mallet compound.

The latest type of locomotive developed for this service constitutes, we believe, the heaviest class of passenger engines extant. The design is illustrated in Plates I, II and III, with this week's issue of ENGINEERING, and on page 27, the engines having been supplied by the American Locomotive Sales Corporation, whose London address is 26, Victoria-

street, S.W. 1. The design includes eight-coupled wheels, 63 in. in diameter on the tread, cylinders 28 in. in diameter with a stroke of 30 in., and a boiler of large capacity, fitted with a superheater, and working at a pressure of 210 lb. per square inch. The tractive power at which the engine is rated is 66,600 lb. the factor of adhesion adopted being 3·86. The large photograph reproduced in Fig. 1, Plate II, gives a very good idea of the appearance of the engine, the details of which are more clearly shown in the elevation, Fig. 2, while end elevations and sections are given in Figs. 3 to 10, Plate I. Of the latter, Fig. 3 shows the elevation at the trailing end of the locomotive, while Fig. 4 is a section through the cab. The half-sections in Figs. 5 and 6 show sections forward of the fire-box, looking towards the rear and front ends respectively. Fig. 7 shows a section taken just ahead of the yoke looking towards the trailing end, while Fig. 8 is a section looking forward showing the second brace carrying the forward end of the slide bars. Fig. 9 is a section through the smoke-box, and Fig. 10 is a half-elevation of the leading end.

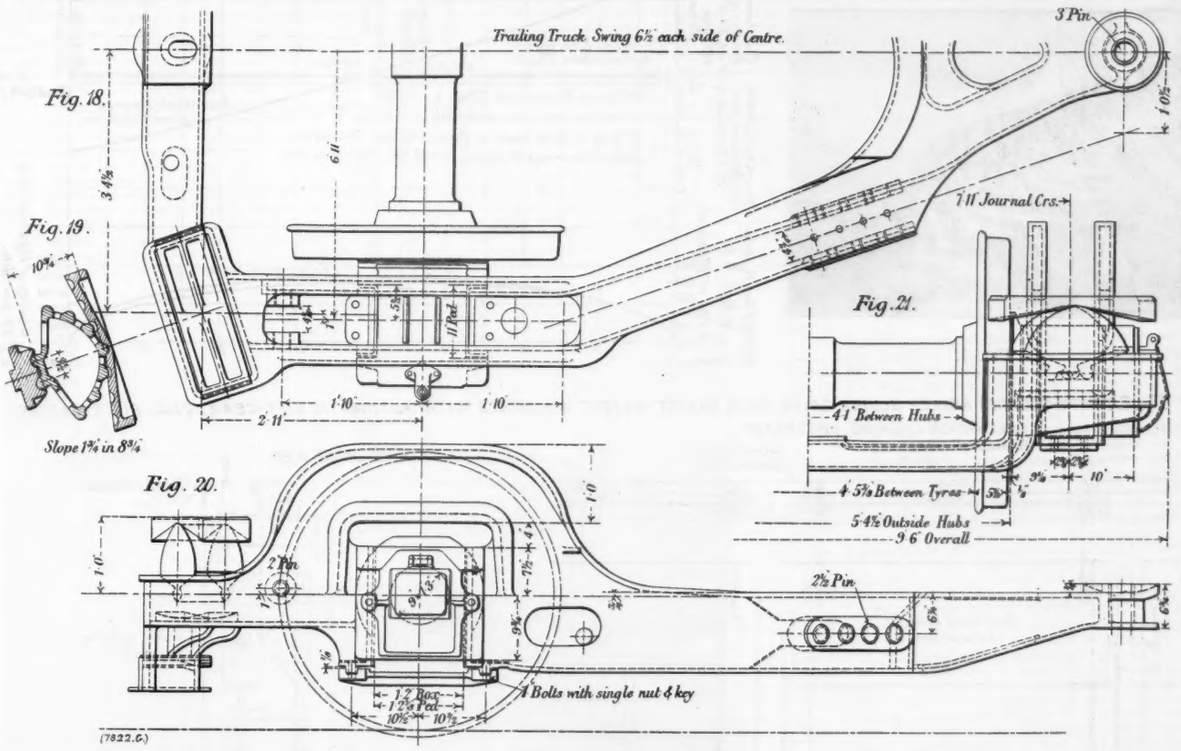
The driving wheel base is 17 ft. 3 in., but as the line is characterised by severe curvature this is reduced by the use of a front floating axle and spherical side rod bushes. The actual rigid base is thus brought down to 11 ft. 2 in., the sharpest curves on the road being of 12° 40′. The side rod bushes are double in the case of the forward rod. An inner bush shaped spherically on the outside is held in a cupped split bush which in turn is held in the rod. The big end of the connecting rods and main pin of the coupling rods are fitted with floating bushes of the type we described in ENGINEERING some time ago.* The engine is fitted with piston valves 14 in. in diameter and with 7-in. travel. The outside lap is $1\frac{3}{16}$ in., lead in full gear $\frac{3}{16}$ in., and clearance $\frac{1}{8}$ in. Double ported valves have been adopted for a second batch of engines of the same type. Power reverse gear is furnished, while the valve mechanism is of the Walschaert type. The crosshead is of the Laird pattern.

The boiler is of the straight-top type with wide fire-box fitted with combustion chamber. The length of the tubes is 20 ft., and the diameter of the front ring of the boiler barrel is $94\frac{5}{16}$ in. Detail drawings of the boiler are given in Figs. 11 to 17, Plate III. The small tubes are $2\frac{1}{4}$ in. in diameter, and the large $5\frac{1}{2}$ in. Together they provide 4,242 sq. ft. of heating surface to which are added 368 ft. provided by the fire-box and the arch tubes. The total thus amounts to 4,610 sq. ft. besides which the superheater surface provided is 1,428 sq. ft. The grate area is 80·2 sq. ft., the boiler being fired by means of a Duplex mechanical stoker.

* See ENGINEERING, vol, cxiii, page 388.

The fire-box has a length of $120\frac{1}{4}$ in. and a width of $96\frac{1}{2}$ in. Liberal water spaces are provided, that in the front leg being 7 in., while at the sides and back they are 6 in.

The engine is provided at the leading end with a four-wheeled Woodard truck. This type of truck is well known, but has not been used in this country. The place of the more usual swing links for the bogie bolster are in it taken by two inverted heart-shaped rockers which are to be seen in the section Fig. 9, Plate I. The trailing end of the engine is carried by the truck illustrated in Figs. 18 to 21, subjoined. This is a radial two-wheeled truck provided with a rocker centering device. The rockers are shown in position in Figs. 20 and 21, and in detail in Fig. 19. The lower support consists of two rounded knife-edges, while the upper supporting surface is struck to two separate circular arcs, the face being finished with ridges or corrugations matching corresponding depressions in the underside of the casting fixed under the main frame. The centres are chosen so that the more



Cylinders, diameter	28 in.	
Cylinders, stroke	30 in.	
Wheels, diameter, bogie ...	33 in.	
Wheels, diameter, driving ...	63 in.	
Wheels, diameter, trailing ...	42 in.	
Axles, journal diameter, main driving	12 in. by 13 in.	
Axles, journal diameter, other driving	11 in. by 13 in.	
Boiler barrel diameter	$94\frac{5}{16}$ in.	
Firebox, length	$120\frac{1}{4}$ in.	
Firebox, width	$96\frac{1}{2}$ in.	
Tubes, length	20 ft.	
Tubes, No. and diameter, small	220—$2\frac{1}{4}$ in.	
Tubes, No. and diameter, large	58—$5\frac{1}{2}$ in.	
Heating surface, small tubes ...	2,580 sq. ft.	
Heating surface, large tubes ...	1,662 sq. ft.	
Heating surface, arch tubes ...	35 sq. ft.	
Heating surface, fire-box ...	333 sq. ft.	
Heating surface, total ...	4,610 sq. ft.	
Superheating surface	1,482 sq. ft.	
Grate area	80·2 sq. ft.	
Working pressure, pounds per square inch	210.	
Chimney, diameter	$24\frac{1}{2}$ in.	
Chimney, height above rail level	15 ft. $9\frac{1}{16}$ in.	
	Tons cwt. qr.	
Weight in working order, on drivers...	114 19 0	
Weight in working order, bogie	25 13 1	
Weight in working order, trailing truck	27 13 2	
Weight in working order, total engine	168 5 3	
Weight in working order, engine and tender	287 15 1	
Wheel base of engine and tender	82 ft. $2\frac{1}{2}$ in.	

The tenders required for such severe service are naturally large. The supply of coal carried is no less than 20 tons, and of water 14,000 U.S. gallons. As will be seen from Fig. 1 the tender is carried by two six-wheeled bogies which have cast steel frames.

The annexed table gives the chief particulars of this locomotive and tender.

THE STORAGE AND DISTRIBUTION OF WATER.*

Improvements in Mechanical Contrivances in connection with the Storage and Distribution of Water.

By E. BRUCE BALL, of Kilmarnock, Member.

VARIOUS more or less standardised and well known devices are recognised for each particular form of water control, but the number of these appliances is so vast that no useful purpose would be served by attempting to present a general view of them all. In the present paper, therefore, reference will only be made to apparatus which has undergone recent development to suit the increasingly exacting requirements of the times. Also, as attention will be confined to mechanical features, it will be impossible to describe the general lay-out and operation of any of the vast water schemes, for which the appliances are required.

OUTFLOW CONTROL FROM IMPOUNDED WATERS.

Artificially impounded water is used for irrigation purposes, for industrial, public and domestic water supply, for generation of power, and for inland navigation improvement. For these objects, some means, either automatically, semi-automatically, or positively operated, must be provided for drawing off or controlling the impounded water as desired, and in some cases mechanical safety devices are necessary to release flood waters. Apparatus of the nature of weirs, shutters, gates, sluices or valves of many different types usually fulfil these functions, and during recent years much attention has been devoted to the design of these appliances. Obviously one of the principal conditions of design is the pressure head under which the appliance has to operate, and it

* Paper read before the Institution of Mechanical Engineers, at Glasgow, June 27, 1923.

will be convenient, therefore, to classify devices with regard to their working head.

(*a*) *Low Head Constructions* would cover apparatus operating at the free surface of the water, and would include—

(1) Collapsible dams, or weir shutters.

(2) Sluices, or regulators, controlling the flow through open channels, barrages across river beds, &c.

(*b*) *Medium Head Constructions* would refer to apparatus are called "drop shutters" or "weir shutters," and they may be applied where the object is to impound water when desired, and to provide a large area flood-gate when necessary. The latest practice is to employ light steel structures for this purpose, which may be either self lowering after release by hand, or automatic in collapsing. Mechanically such a shutter must be light enough to be lifted with comparative ease, strong enough in every detail to withstand the shock of falling, weir shutter, developed by Major John Ashford, O.B.E., M.I.Mech.E., of the Punjab Irrigation Department (India). This is of the strut supported type, as illustrated in Fig. 1, showing the shutters in action. The strut support is hinged and anchored to the weir crest at one end, while the other end slides in a groove on the back of the shutter. When the shutter is erect, the strut is locked by a catch which has a projecting trigger overlapping the neighbouring shutter. When the end

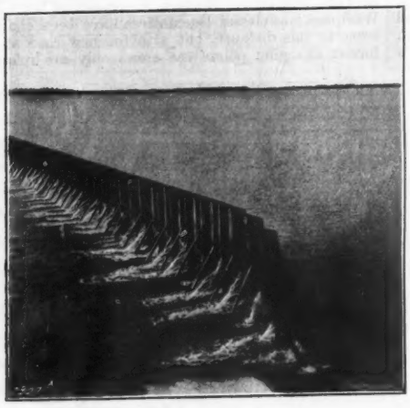


FIG. 1.

Fig.3. ENERGY DIAGRAM FOR SLUICE-GATES.
EMPTY GATE (GEAR FRICTION CONSIDERED) VAAL RIVER BARRAGE

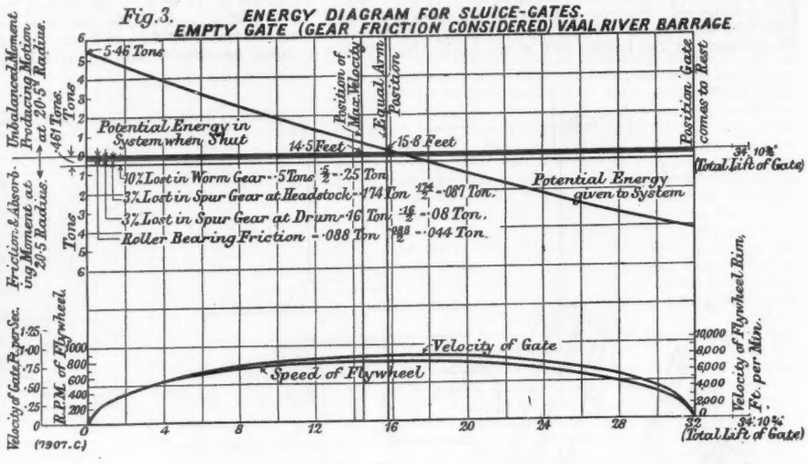
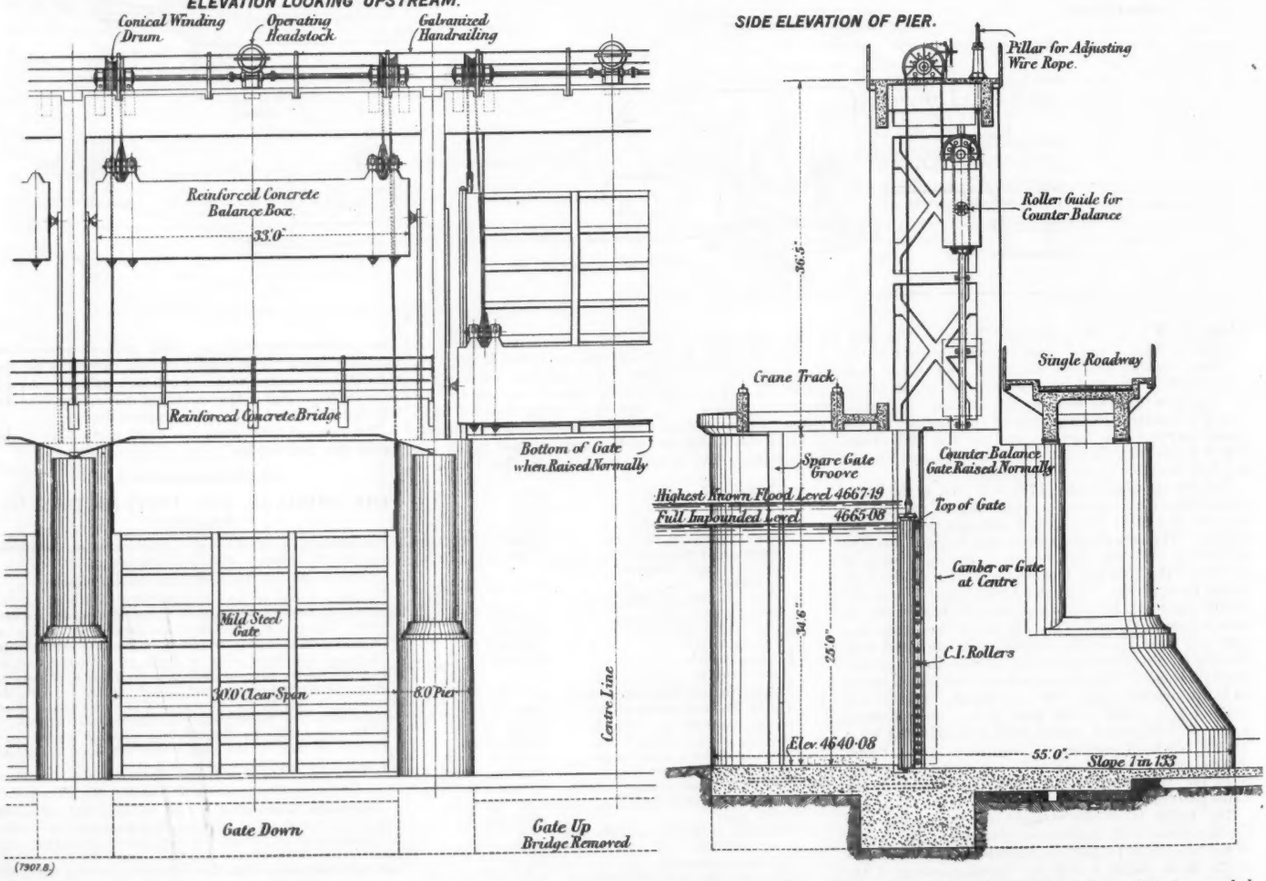

5·46 Tons
Unbalanced Moment Producing Motion at 20·5 Radius
·461 Tons.
Tons
Potential Energy in System when Shut
Position of Max. Velocity
Equal Arm Position
14·5 Feet
15·8 Feet
Position Gate comes to Rest
34' 10⅝" (Total Lift of Gate)
10% Lost in Worm Gear - 5 Tons - ·25 Ton
3% Lost in Spur Gear at Headstock - ·174 Ton - ·087 Ton.
3% Lost in Spur Gear at Drum - ·16 Ton - ·08 Ton.
Roller Bearing Friction - ·088 Ton - ·044 Ton.
Potential Energy given to System
Friction & Absorbing Moment at 20·5 Radius
Velocity of Gate Ft. per Sec.
R.P.M. of Flywheel
Velocity of Gate
Speed of Flywheel
Velocity of Flywheel Rim Ft. per Min.
(7907.C)

Fig.2. THIRTY-SIX FREE ROLLER SLUICE-GATES EACH 30 FEET x 24 FEET 4½ INCHES WITH AUTOMATIC LIFT-GEAR. VAAL RIVER BARRAGE



normally submerged, but to no great depth, and would include undersluices for low dams, submerged undersluices in a river works, dock sluices, reservoir draw-off sluices, &c.

(*c*) *High Head Constructions* would be submerged apparatus working at greater depths, such as undersluices for high dams, and sluices in culverts.

Collapsible Dams.—Where impounded waters are liable to the influx of flood water, it is often convenient to construct the dam, or the crest of the dam, or portion only of the crest, as a mechanical contrivance, which can be raised or collapsed as desired. Such devices simple in design, and unaffected by silt and detritus. It must be easily handled by unskilled labour, both as regards dropping and resetting vertically, and must possess a high degree of durability under the severe conditions of exposure, river action and rough usage, thus requiring the minimum of repairs, and these of the simplest possible nature only. Finally it must be absolutely certain in action, both as regards falling and resetting.

A recently perfected drop shutter which seems to fulfill all these requirements, and has now been under service in experimental forms for several years, is the Ashford leaf is released it falls under the pressure of the impounded water, and in falling trips the projecting trigger of its neighbour. This leaf in its turn trips its neighbour, and so the whole series fall in sequence. In the simplest arrangements the release of the first leaf is effected by a small lever controlled from a pier or abutment, and arranged above the maximum flood level, so that the shutters can be operated even when they are "overtopped" by the flood water. In other cases automatic means, controlled by the water level itself, are preferred for releasing the first shutter. The resetting operation is facilitated by the provision of a gantry crane as

included in apparatus recently supplied to the Bloemfontein Corporation for Mocke's Dam, South Africa. In this installation there are 162 shutters stretching over a width of 404 ft., each shutter being 5 ft. high by 2 ft. 6 in. wide. Release is from one end only, and may be effected by hand or automatically when the flood water rises to a height of 2 ft. over the shutters. The automatic gear consists of a cylindrical tank into which water flows when a predetermined flood level is reached; the tank falls as it fills and unlocks the first shutter through a suitable link and chain arrangement, the whole line of shutters then collapsing. The gantry is used to lift up each shutter individually, and the relocking is performed by one man following the gantry on the crest of the dam. When raised these shutters are quite watertight, a flexible balata joint being arranged at the sill level, and wide balata flaps at each vertical joint between the leaves.

To secure closer control of the impounded water, the shutters may be arranged in groups, each of which is provided with a separate release lever controlled from an abutment, thus any number of groups can be dropped at will while the remainder are left standing, or the whole line can be made to fall in the usual manner.

Sluices or Gates.—Large modern sluice gates employed as canal regulators, open channel sluices and dam undersluices, &c., would be of a built up steel construction with flush upstream surface, fitted with anti-friction devices throughout and with either simple or self-starting lifting gear, positively or automatically controlled.

The principal dimensions of clear span, height, and lift are determined by the conditions at the site, and the mechanical engineer rarely has any choice in this respect. Where a long length of sluices is to be installed, however, he may be called upon to provide gates of the largest possible span, in order to reduce the number of piers to a minimum, thereby cheapening the masonry work and the structural work at the same time, and also, in the case of spanning a natural river bed, offering the minimum area of obstruction to flow. In this connection it may be said that gates have been made up to 80 ft. span, and practicable designs exist for gates of 100 ft. width. In fact, from the mechanical side the limit of length has not yet been reached.

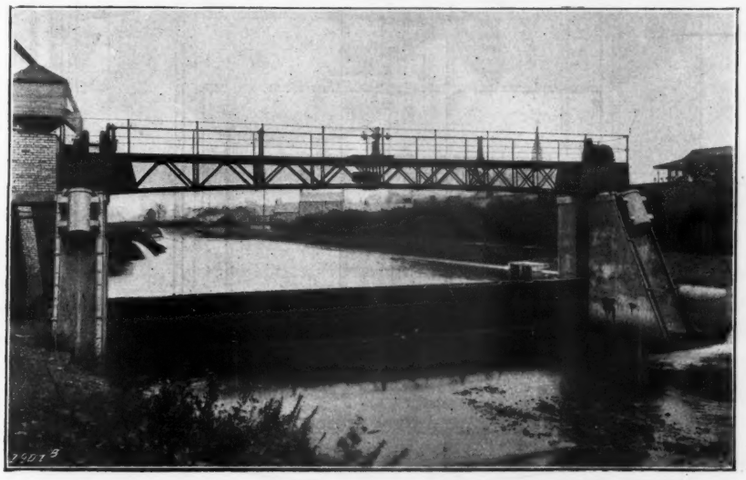


FIG. 4. RIVER IRVINE SLUICE, DOWNSTREAM SIDE.

Features in which different sluice gates vary, are in the design of the superstructure and lifting gear, and in the anti-friction details, and the staunching device. Little difference is noticeable in the construction of the gate itself. Heavy sluice gates are provided with counterbalance weights to relieve the lifting gear of all dead weight, and it is usually convenient to arrange this balance weight in the loop or "bight" of the hoisting rope, so reducing the height of the superstructure.

Superstructures are of three accepted types:—(1) Ferro-concrete throughout—generally with ferro-concrete counterbalance weights; (2) with concrete columns and overhead lattice steel cross beams; and (3) all steel structures, with steel balance boxes loaded with ballast. The principle followed in design is to make the column with a short cantilever head, so that the dead weight of sluice gate and counterbalance is carried on the cantilever, and then to connect the columns by a lightly braced crossbridge practically free from bending moment, and sufficiently strong only, to support the central operating gear.

Operation is usually by a simple winding gear with or without self-starting, accelerating or retarding devices. Winding drums are provided at each end of the gate, paired, with oppositely handed helical grooves for the hoisting rope, to give parallel motion to gate and counterbalance weights. The suspension shackles on the gates are also adjustable so that they may be set towards the front or the back to cause the gate to hang truly vertical.

To eliminate the friction due to thrust it is usual to provide rollers for the gate to run upon. These rollers are of two types—(1) "Fixed rollers" which have the effect of converting sliding friction into spindle friction, and (2) "Free rollers," which convert sliding resistance into pure rolling and practically eliminate friction altogether.

The original "fixed rollers" were small wheels rotating on plain pins, recessed into the sides of the gate and arranged to run on a smooth track fixed to the gate groove in the masonry piers. These simple rollers frequently jammed on the spindles through silt and rust, and were rendered totally ineffective for their purpose. A modern improvement is Ashford's roller bearing roller box, in which the roller is encased in a close fitting grease filled box, and runs on roller bearings corrosion being eliminated and the spindle friction reduced to a minimum.

The original "free roller" was developed some fifty years ago by the late Mr. F. G. M. Stoney, and has been materially improved since. With this device a train of rollers is suspended in the gate groove in such a manner as to *conform* to their natural movement. With these rollers axle friction is entirely eliminated as they simply roll between their two paths at half the relative movement of the paths, transmitting any thrust directly across their diameters from one contact line to the other contact line. On account of the great width of modern sluice gates and the difficulties of securing perfect alinement in a structure made up of a combination of masonry and steelwork, the roller paths must be housed flexibly relative to each other, so that under the hydraulic pressure on a gate the two paths are alined and the roller is free to roll truly between the two. In the past the flexibly housed path has been accommodated in the check groove on the masonry abutments, where it remained submerged and inaccessible when the gate was lifted. One of the latest improvements to the free roller sluice consists in attaching the yielding path to the gate itself, then when the gate is raised, this improved construction brings all the moving parts clear of the water and presents them regularly for inspection.

To produce a reasonably watertight sluice the latest practice is to provide a cast-iron sill suitably formed to carry a renewable teakwood face for the gate to seat upon, and this, combined with an adjustable edge on the gate itself, forms a satisfactory joint. The sides are usually provided with a staunching rod of steel, or brass tube, suspended from the gate and arranged to be forced by the water pressure into the angle between the extremity of the gate and the side of the gate groove. This staunching rod is machined, and faced bronze strips are provided for it to bear upon, one on the side of the groove, and the other on a machined face of the rigid end post of the gate in preference to the rough skin plate of the sluice gate.

An interesting example of a typical modern construction is provided by the Vaal River Barrage, South Africa, only recently completed.*

The barrage is 1,400 ft. long and includes 36 free roller sluices, each 30 ft. wide by 25 ft. 4½ in. deep, the general arrangement of which is shown in Fig. 2. The superstructure and counterbalance weight are of reinforced concrete, and the gates of mild steel working on free rollers. Each gate weighs 28 tons and sustains a total water pressure of 293 tons under the maximum impounded height. The counterbalance is weighted to 56 tons, and a differential winding gear is provided to give automatic self starting for both raising and lowering. This operating gear is shown in Fig. 2, and an explanatory energy diagram in Fig. 3. The hoisting rope passes over a double-cone drum interposed between the sluice gate and the counterbalance weight, so arranged that at the extreme positions of gate travel, the respective weights act alternately at long and short leverages. When the gate is closed its lifting rope is on the small diameter of the drum, while the rope carrying the counterbalance weight is on the large diameter. The gate is then overbalanced by the greater moment due to the counterbalance weight, and the excess moment is therefore held on a pawl. To open the sluice it is only necessary to release the pawl, the balance weight then falls, gathering speed as shown on the diagram until a point is reached at which the moments of sluice and weight are equal and opposite. During this movement the weight has been acting at a steadily reducing leverage while the gate leverage has been steadily increasing. The kinetic energy in the system then continues the movement, work being done to overcome the continually increasing moment of the sluice gate as its hoisting rope runs up the increasing radius of the fusee drum. When all stored energy is expended the gate stops and its tendency to fall is at once checked by another pawl. The travel of the gate under this self propelled action is about 32 ft., and the remaining 2 ft. 10½ in. lift is carried out by hand. The gate is then ready to be lowered at any time by simply releasing the retaining pawl, when it will run down to within 3 ft. of the closed position, leaving the final closing movement to hand operation.

A flywheel is added to the operating gear to act as a time control device, and the effect of this is included on the energy diagram. The mass of this wheel determines the rate of acceleration of the falling weight, and also its rate of retardation towards the end of the movement, thus determining the time of raising or lowering the gate. This is a sensitive and exceedingly valuable contribution to the efficient behaviour of an automatic gate, and was first introduced on the Vaal River Barrage. In this particular application the automatic gear is timed to give a mean gate velocity of 0·66 ft. per second, and a total travel of 32 ft. in 48 seconds with the gate working dry, and tests taken on the site have confirmed these times.

A very important feature of the self-starting gear is that it reduces the amount of labour to a small fraction of that required for a hand-operated gear, and the tedium of lifting a large gate gives place to the comparatively light work of completing the movement only of each gate.

An operating gear practically identical with this has also been fitted to the sluices at Lake Mentz Dam, South Africa, where the five sluice gates are 30 ft. span by 25 ft. high, the superstructure in this case being reinforced concrete uprights with lattice steel crossbridges.

In other cases the self starting action is carried out by giving an initial acceleration only. Instead of the double-spiral or fusee winding drum, a parallel drum is fitted and a cam provided at each end of the rope groove, so that either the gate or the counterbalance weight is overbalanced at the start and finish only. This gives an accelerating action to commence with and a retardation at the end of the movement. An example of this form of gear occurs on the sluices at Badlapur Barrage, Bombay. In this installation there are four deep sluices, 42 ft. span by 16 ft. 6 in. deep, and one shallow sluice, 52 ft. span by 10 ft. 6 in. deep, this special arrangement being designed to conform to the contour of the very hard rock bed at the site. The superstructure is entirely of steel and the gates run on free rollers as usual. Special interest is attached to the automatic release in this case. In one abutment a chamber is provided to accommodate a suspended cylindrical tank, into which water flows whenever the impounded water reaches a predetermined level. The weight of this tank, when filled, causes it to fall and release the pawl sustaining the overbalanced counterweight of the first sluice gate. This gate then lifts automatically and, in its movement, it trips the pawl of the neighbouring sluice and so on until all the sluices are opened. The automatic gear does not fully raise the gate, but it acts as an automatic relief in case of sudden floods, and with this gear the completion of the lifting or closing operation is also done by hand.

It is interesting to notice that this form of trip gear is particularly suitable for positive remote control of sluice gates, either by direct mechanical means or by electrical agency. As an additional safeguard to the efficient control and protection of many important water schemes there is, in many quarters, a growing demand for reliable means of remote control, and undoubtedly engineers will give this important question increasing attention.

An instance where the gates are operated entirely by hand, without any automatic gear or accelerating and retarding devices, occurs at the Decha Barrage (India), now under construction. This plant has an all steel superstructure and is provided with 11 sluices, each 40 ft. span by 12 ft. high; also at Prasak Barrage, Siam, operation is by hand only, and these sluices are amongst the largest individual gates yet made. The clear span is 41 ft. and depth 24 ft. 7in. the total weight of each gate amounting to 41 tons and the gate pressure totalling 375 tons, thus furnishing remarkable evidence of the efficiency of the free roller device when it is considered that these heavy loads are dealt with by simple hand operation.

An interesting single span small river sluice is shown in Fig. 4. This serves the purpose of a removable dam intended to secure a constant supply of condensation water to a large power station. The clear span is 70 ft., and impounding height 7 ft., and the gate is provided with a free roller train and counterbalance weight running on inclined paths, conveniently arranged on the downstream side of the abutments piers. This sluice is easily operated by one man and is regularly raised or lowered in less than 2 minutes.

Attention has so far been devoted to large single-leaf sluices. For canal regulation and similar work, identical types are made in narrower widths and smaller depths. Two and three leaf sluices, however, are also general for such cases, the object of multiple leaves being to permit top water with the least burden of silt to be drawn off into the canals.

The multiple leaf sluice in some forms does not lend itself to the employment of the free roller train; hence

* *The Engineer*, December 1, 1922.

it is common to fit "fixed rollers" in many instances, either to one or more of the leaves. An example of a canal regulator installed at Jamshora for the Fuleli Canals District, India, is given in Fig. 5. There are seven double-leaf sluices at this site, six with a clear span of 15 ft., and one with a span of 20 ft., each leaf of each double sluice being 12 ft. 6 in. deep. In this case the wide span sluice is provided for the purpose of giving free navigation space through the regulator, and a specially high superstructure is fitted over this span for the same purpose. The control is by hand operation through worm and spur gearing, with an independent control of each leaf. As shown on the drawing a free roller train is fitted to the lower leaf, and fixed rollers to the upper leaf of each sluice regulator.

Roller Sluices for Higher Heads.—Anti-friction rollers are also applied to sluices operating at depths well below the up-stream water surface. One example only will be sufficient to indicate the type of modification necessary for this class of work. Fig. 6 shows a roller sluice installed at Haartebeestpoort Dam, South Africa, with a maximum head of 71 ft. above the centre of the sluice door. The joint face is angled slightly from the perpendicular, while the rollers run on vertical paths. The result is that the gate is actually lowered and raised vertically from the joint, the great pressure on the gate bringing it to rest immediately the faces come in contact and before any sliding occurs of one face over the other; as an additional convenience in operation, a two-speed headstock is provided, so that the low gear may be used when the sluice is near the closed position and the high gear for quicker movement when the load on the gate is less.

In the above case the rollers are of the "fixed" type, but the "free-roller" is equally well arranged on sluices of this kind. In all cases it is desirable to accommodate the sluice in a well where sufficient space is allowed for the gate and rollers to operate, and into which access can be obtained for dismantling and inspection after previously staunching the opening from the reservoir into the gate well.

Reservoir Draw-off Appliances.—Ordinary sluice valves with casing and simple forms of sliding sluice are often used for drawing off storage water from reservoirs, also special arrangements, such as draw-off towers, cylindrical valves, or special regulator valves are often specially designed for the occasion.

A draw-off tower, either of the wet or dry type, may serve a number of purposes—it enables water to be drawn off from any desired level in the reservoir, and permits of operating each sluice under a reasonably low head, it allows ready access to valves or sluices, and frequently allows of providing simple screening facilities in an accessible manner.

In a recent development of wet draw-off tower, an upper and a lower cylindrical valve are provided for extracting water from either of two levels, and with an interlocking gear designed to prevent the two valves being operated simultaneously. At each level there are four inlet ports provided with gratings and fitted with additional single-faced sluices. These ports are arranged to deliver jets mutually opposite, so that the impact dissipates the kinetic energy in the stream and removes tendencies to vibration. The valves are perfectly balanced and free from thrusts on the working faces, and are therefore very easily operated, also they are readily adjustable, and act as regulators controlling the quantity of water drawn off from the reservoir. All wearing surfaces are gun-metal fitted, and the controls are through the usual worm-geared headstocks. A pit at the bottom of the downcast forms a "water cushion" and ensures a steady flow at the outlet. By closing the flat sluices, the main cylindrical valves are left dry, and may be reached for examination. A similar arrangement may be employed as a single valve for drawing off water from one level only as at Sunday's River Irrigation Scheme, Lake Mentz Dam, South Africa, where the diameter of the cylindrical valve is 5 ft. This form of valve is particularly suitable for hand-controlled regulation, as the discharge streams through the valve are free from turbulence for all positions of opening.

Stream-Lined Valves.—One of the most interesting developments of recent times is the extension of the well-known principle of "stream lining" to very large water valves, and of this departure the Johnson-Boving valve forms an example. In these valves the movable member is operated by hydraulic pressure, and the parts so proportioned that the head in the pipe itself is sufficient to produce all the movements necessary. The valve is shown diagrammatically in Fig. 7, which also embodies a simple form of pilot or control valve. The casing A is provided with a machined inner cylinder in which slides the piston extension of the trunk valve C, the trunk portion of the valve also being guided at the neck extremity of the inner cylinder. Two joint seats are provided for the valve to close upon, and the centre space

Fig. 5. JAMSHORA REGULATOR. CROSS SECTION.

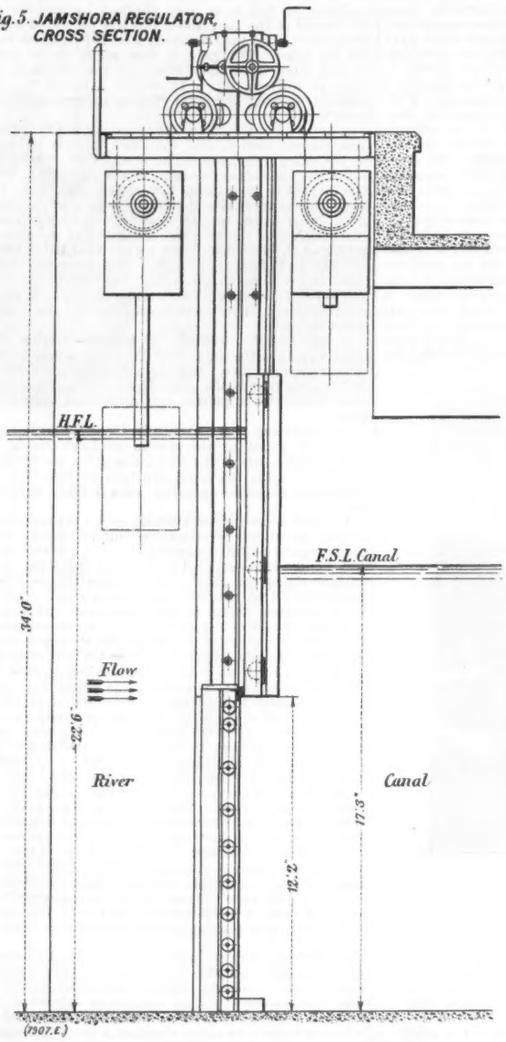


Fig. 6. ROLLER SLUICE FOR MEDIUM HEADS. HAARTEBEESTPOORT DAM SLUICE.

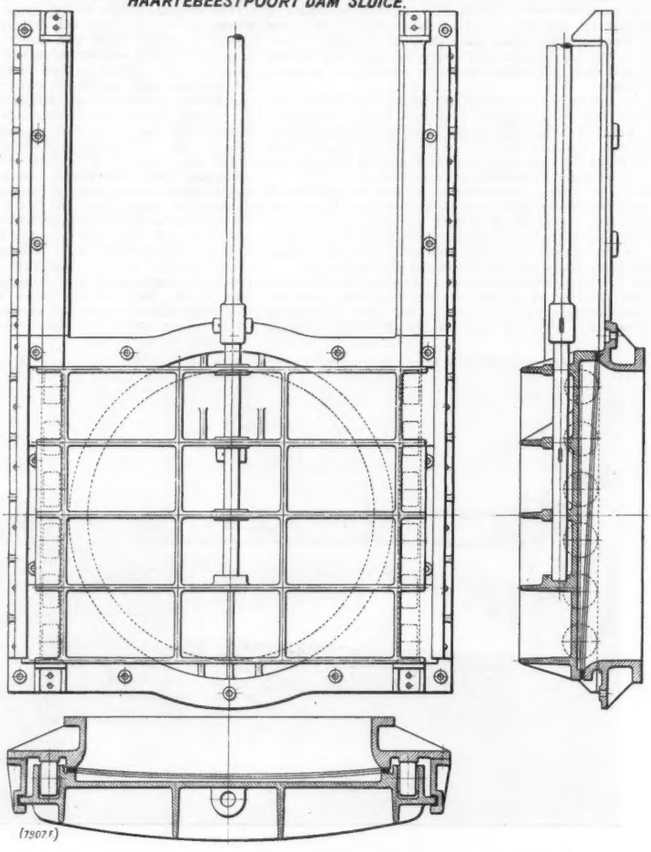
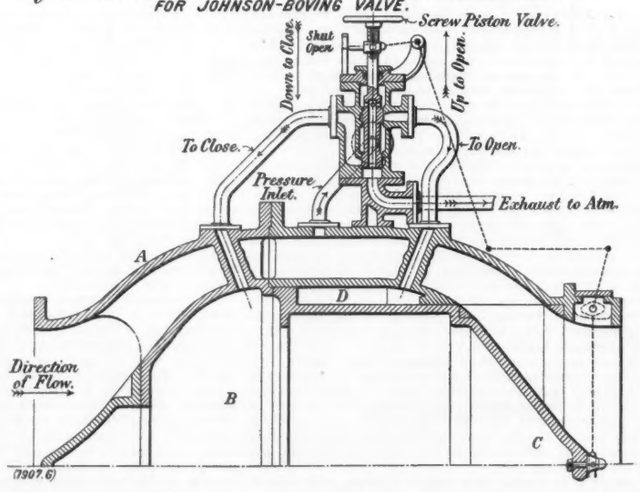


Fig. 7. DIAGRAMMATIC ARRANGEMENT OF OPERATING CONTROL VALVE FOR JOHNSON-BOVING VALVE.



is divided into two water chambers, B and D, each of which is provided with a port communicating with the exterior of the casing A. To close the valve, pressure is admitted to B, and D is exhausted to atmosphere; to open the valve B is exhausted, and D is connected to pressure. This type of valve forms a class by itself, as it may be applied equally well to duties formerly met by sliding sluices, sluice valves or throttle valves, and considerable experience has now been obtained on such applications as reservoir draw-off valves, dam under-sluices, water-power control valves, &c.

It will be seen that the valve is only slightly greater than the pipe diameter itself, and occupies very little

A simple control gear consists of a four-way valve, so arranged that it alternately connects either one of the internal water chambers with the pressure supply and the other chamber simultaneously with exhaust to atmosphere. In recent constructions this pilot or control valve has been made as a piston valve, as shown diagrammatically in Fig. 7, and operated by screwed rod and hand wheel so that a gradual pressure change is brought about and reasonably slow movement of the main valve thereby secured. This piston form of valve is readily combined with a "return gear" operated by the main valve, and by which the piston-valve is "returned" to its neutral position as soon as the main valve has

set of eight valves supplied to the Public Works Department, New South Wales, for the Sydney Water Supply Scheme. Four of these valves work under pressure of 100 ft. of water, and four of them at 200 ft., delivering impounded water freely into a rocky water bed. In this case the indicating gear has two scales, one showing the position of the operating valve at any time, and the other the position of the main valve. These valves are made of cast-iron throughout, and gun-metal fitted wherever movement occurs.

For high-pressure conditions cast-steel bodies and valves are adopted, as in a recently-completed installation for the Mangahao Hydro-Electric Scheme, New Zealand.

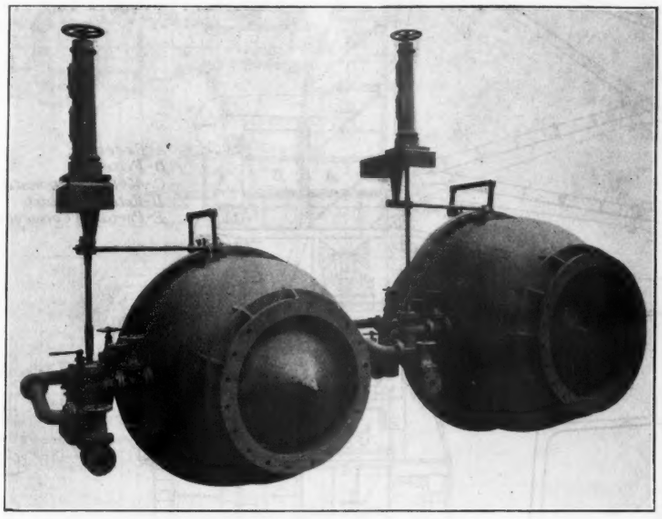


FIG. 8. VALVES FOR SYDNEY WATER SUPPLY (JOHNSON-BOVING).

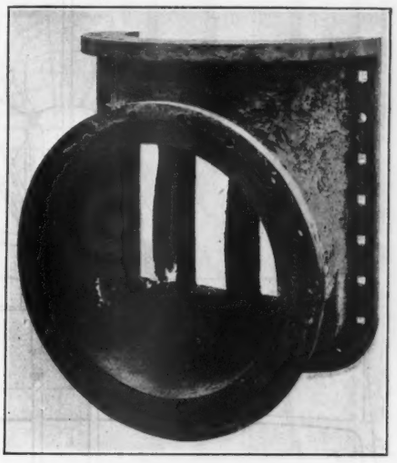


FIG. 9. ERODED SLUICE CASING.

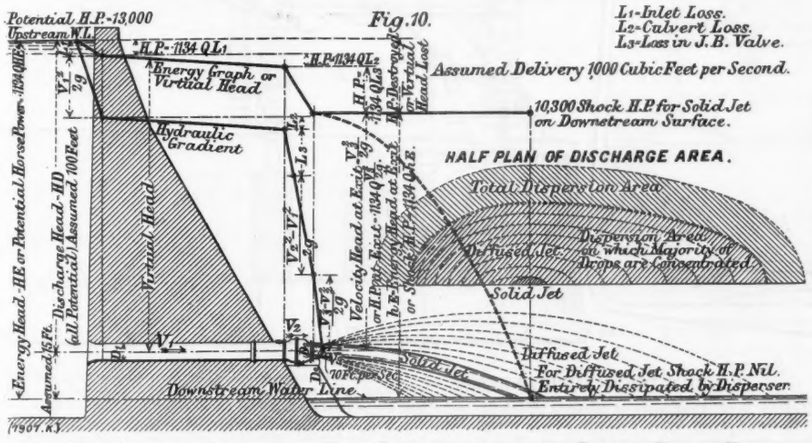

Potential H.P.-13,000
Upstream W.L.
H.P.-1134 Q L1
H.P.-1134 Q L2
Energy Graph or Virtual Head
Hydraulic Gradient
Virtual Head
Assumed Delivery 1000 Cubic Feet per Second.
10,300 Shock H.P for Solid Jet on Downstream Surface.
HALF PLAN OF DISCHARGE AREA.
Total Dispersion Area
Dispersion Area on which Majority of Drops are Concentrated
Diffused Jet
Solid Jet
Diffused Jet
For Diffused Jet Shock H.P. Nil.
Entirely Dissipated by Dispersion
Downstream Water Line
70 Ft per Sec.
L1-Inlet Loss.
L2-Culvert Loss.
L3-Loss in J.B. Valve.
Energy Head-HE or Potential Horse Power-1134 Q HD
Assumed 100 Ft. Discharge Head-HD (all Potential) Assumed 100 Feet
(1907. K.)

Fig. 10.

FIG. 10. HYDRAULIC DIAGRAM OF FREE DISCHARGE THROUGH A JOHNSON-BOVING VALVE.

ENERGY GRAPH: Measured from the culvert centre line to the same scale as the dam section. The ordinate under the energy graph gives the "virtual head" present in the flowing water at any point, and the fall in graph gives the head destroyed by friction or turbulence. Measured from the downstream W.L. to a unit 0·1134 Q times as great, the same graph gives the horse-power existing at any point, and the fall in the graph gives the power absorbed in erosion, friction and turbulence.

HYDRAULIC GRADIENT: Measured from the culvert centre line to the scale of the dam, the ordinate gives the pressure (static or potential head) existing at any point in the discharge culvert.

extra space, no operating mechanism is exposed to the action of the water, and the linear movement of the valve is only about a quarter of that of a sluice valve of corresponding dimensions. The deflection given to the water stream is of a type well known to absorb an exceedingly small amount of head, and to give smooth undisturbed flow, the frictional resistance due to the valve is therefore very slight indeed. On account of the large areas provided in the internal water chambers enormous forces are available, if required, to move the valve; consequently the device may remain in one position for long periods and will function with ease and certainty when required. As regards water-tightness the design provides circular joint seats which cannot distort under load, and the available pressure for holding the valve tight is a function of the pressure in the main itself, so that the higher the water pressure, the greater the joint pressure. Also there is no mechanical wear on the joint due to one seat sliding over the other, and, in consequence, the joint faces maintain their condition almost indefinitely.

In order to show the position of the internal valve at any time, it is usual to provide a simple indicating pointer, and this indicating gear is often designed in combination with the control gear.

moved a distance corresponding to the amount of displacement given to the piston valve.

This control is quite definite and self-correcting in its action; it retains the main valve at any position in which it is left, and, if through any cause, the main valve should be disturbed in either direction, a corresponding displacement would be caused to the piston valve, the effect of which would be to restore the main valve to the position set. When the main valve is at rest, in any intermediate position, the piston valve is always in the central position. Any displacement of the piston valve is temporary only, as it is immediately followed by a corresponding movement of the main valve, which movement is itself limited by the amount of displacement given to the piston valve. When it is desired to maintain the valve fully opened or tight closed, and to retain it in that position under pressure, the piston valve is displaced an extra amount in the required direction, thus keeping open the necessary connection between the particular inner chamber and the pressure water. This operating gear may be controlled at the valve by a hand wheel, or remote control by small electric motor or solenoid.

A pair of Johnson-Boving valves with full control and indicator gear are shown on Fig. 8. These are two of a

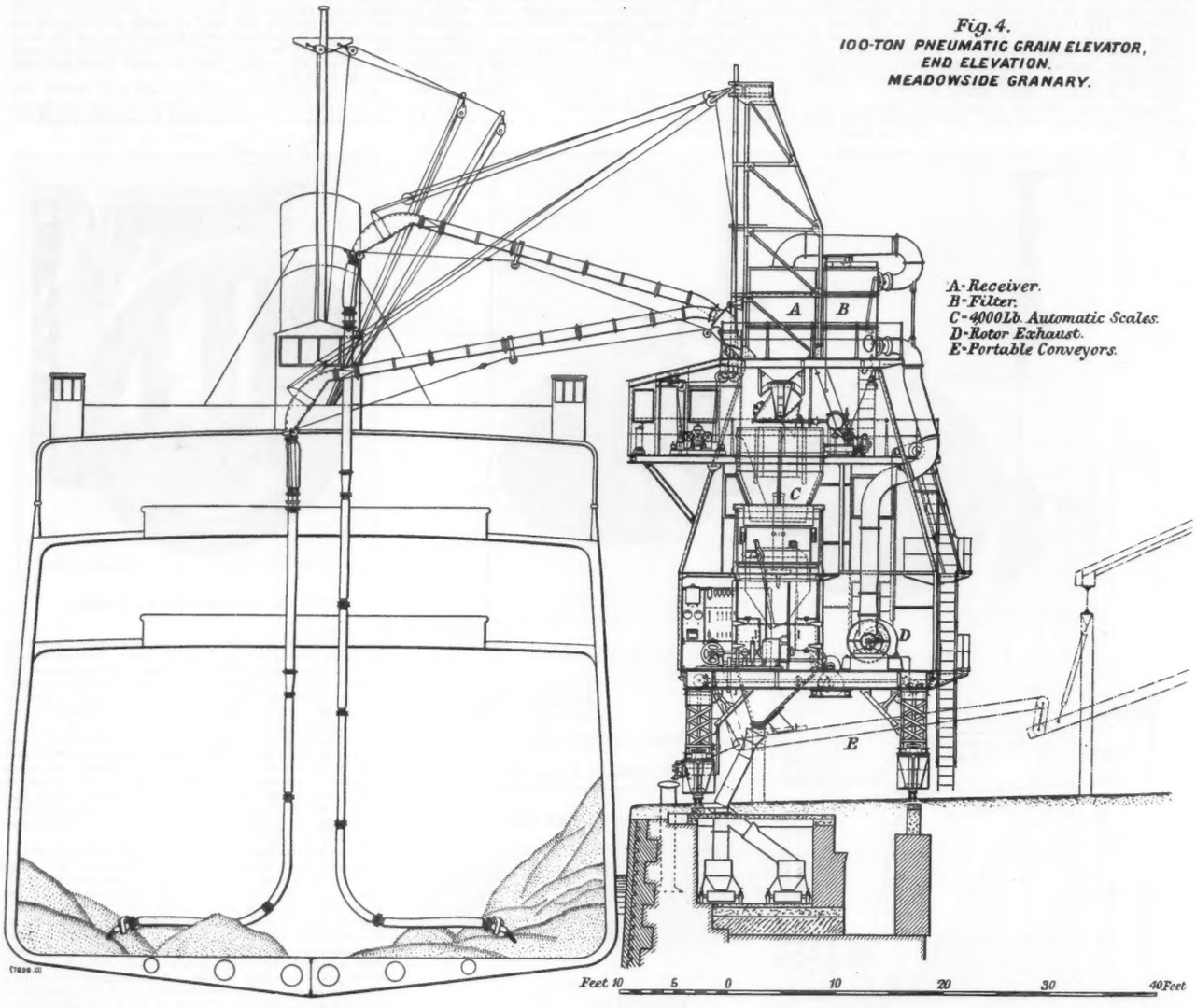
For this scheme nine valves of various sizes were employed, the three largest being 32 in. diameter, subjected to a working head of 1,000 ft. of water. The pressure for opening and closing the valves is taken from the mains, and operation is either by hand at the valve or remote control through a small electric motor geared to the hand mechanism. This plant forms a typical example of a Johnson-Boving valve applied to a pipe line. The movement of the main valve is absolutely under command—it can be set so as to maintain the rate of discharge constant at any required quantity from a maximum at full open to a mere dribble with the joint faces only just apart. Also the valve can be closed at an extraordinary slow rate if necessary, or on the other hand, it can be closed as rapidly as desired.

Reference has been made to the application of streamlined valves to duties formerly carried out by sliding sluices. A typical example would be the control of an outlet from a high dam. As a rule, such an outlet delivers water freely into the air at a high velocity, and in some cases it is necessary to regulate the discharge by throttling. The difficulty of meeting these conditions with a sluice increases considerably as the height of the dam increases. With a throttled outlet it is exceedingly difficult to avoid vibration and serious erosion. A particularly interesting example of the type of erosion referred to is furnished by the engraving, Fig. 9. This is a 27-in. two-door sluice valve body, which has been discharging freely under a head of 160 ft. (corresponding to a velocity of about 100 ft. per second), but partially opened only on one of the doors so as to throttle the escape. After about seven or eight years' service the metal was attacked to the remarkable extent shown in the engraving. None of these difficulties occur when a Johnson-Boving valve is installed—the pressure of water behind the dam is more than sufficient to operate the valve, and the shapes of the water passages are ideal for throttling without vibration. A case in point, where Johnson-Boving valves have been substituted for ordinary sluices occurs at Kinlochleven Hydro-Electric Plant, Argyllshire. Water is drawn off from Blackwater Dam through three 42-in. pipes originally controlled at the up-stream end by ordinary sluice valves, and is discharged freely into a penstock chamber. With three large outlets close regulation of the draw-off from the dam was not possible without throttling the escape, and in practice, when adjusting the discharge to suit the demands of the water turbines, the sluices were seldom fully opened. The maximum head over the sluice is about 72 ft., which, under a free discharge, is sufficient to give a very high velocity through the sluice. Experience with the throttled sluice showed excessive vibration in the pipe, and special steps had to be taken to safeguard the dam. Two of the outlet pipes are now controlled by Johnson-Boving valves placed at the down-stream end of the pipes, and operated by gear of the type shown in Fig. 7, page 30, with which perfect regulation is obtained and smooth jets free from vibration at all rates of discharge. The operating pressure is taken from the pipe itself under the head existing in the dam, and, as a precaution against all possible difficulty in operating the valve when the impounded water level is down to the last few feet, a small hand pump is provided to supplement the pressure when required.

A typical arrangement of a Johnson-Boving valve on a dam and delivering impounded water freely into the air

MODERN DOCK APPLIANCES AT GLASGOW.

Fig. 4.
100-TON PNEUMATIC GRAIN ELEVATOR, END ELEVATION. MEADOWSIDE GRANARY.



is shown by Fig. 10 on the preceding page. No cavity is required in the dam section, a pipe or culvert with a suitably splayed up-stream inlet is carried through the dam and the valve fitted at the down-stream outlet. As the control is at the down-stream end, the bore of the culvert can be kept large so as to eliminate the wear and tear due to an excessively fast stream. The diagram also shows the "pressure gradient" when the outlet is discharging freely, and an "energy gradient" under the same conditions. Quite normal figures have been assumed when working out these gradients, so as to show the magnitude of the forces released. The energy in a single jet passing 1,000 cub. ft. of water per second under a head of 100 ft. after all losses have been deducted is about 10,000 h.p., and in many cases there would be several such jets discharging from one dam. All this enormous energy must be expended in some way, and a common practice is to provide a water cushion to absorb the jets. Experience has proved, however, that a water cushion is not a complete solution of the problem, for quite apart from the erosive effect of the direct impact of the jet, violent swirling currents are set up which carry injury to the banks and surrounding structures, and which set stones and loose boulders in motion, so that they grind away the water bed at a rate very much greater than that due to the action of the water alone. This problem of energy dispersion has led to the investigation of the possibility of dissipating the solid jet by the creation of a free-vortex condition at the outlet, and highly satisfactory results have already been obtained. The free vortex is generated with a negligible amount of back pressure, and when released is rapidly shattered into an immense number of uniformly small drops which are cushioned against the atmosphere and fall on the down-stream water surface as heavy rain deprived of all destructive energy. The comparative effect of discharge with and without dispersion is indicated on the diagram.

(To be continued.)

MODERN DOCK APPLIANCES.

*Modern Dock Appliances at Glasgow Harbour including the Handling of Grain in Bulk also Dredging Plant.**

By DANIEL FIFE, Mechanical Engineer, Clyde Navigation Trust, Glasgow, Member.

(Continued from page 822 of our last volume.)

PNEUMATIC GRAIN ELEVATOR AT MEADOWSIDE.

THE grain intake plant at Meadowside granary† originally consisted of two movable bucket elevators, each of 250 tons maximum capacity per hour, which are placed on the quay close to the granary. These elevators are of the balanced girder type with telescopic shoots to auxiliary elevators which discharge the grain into the top hopper of the weighing machines, and thence by telescopic pipes to subway bands which convey the grain to the granary. It was found, after these machines had been in use for some time, that ships loaded with parcels and part cargo of grain, of which there are a considerable number discharged at Glasgow, were not economically dealt with, and that serious delays occurred owing to grain being stowed out of reach of the bucket elevator legs. After investigation and inspecting plants at various ports, the trustees decided to instal at Meadowside a pneumatic elevator of 100 tons capacity per hour, the structure to be arranged to travel along the quay and traverse so that it could be placed to discharge a ship either between the two bucket elevators or with the bucket elevators amidships; the new elevator could be placed at either end of vessel. The contract was placed with Messrs. Henry Simon, Limited, Manchester, and in June, 1922, the plant was put into service.

* Paper read before the Institution of Mechanical Engineers at Glasgow, June 27, 1923.

† See ENGINEERING, Vol. XCVIII, pages 523, 581, 633, 693.

General Description.—The structure throughout is of steel, the design being as shown by Fig. 4 above, and is supported on a portal carriage of 20 ft. wheel base. The longitudinal steel girders forming the undercarriage are of the braced type and connected by deep beams with intercostal stiffening, plated on top to form the first floor and machinery room in which are placed the exhauster, travelling, jacking and portable conveyor motors, and the main switchboard. The superstructure is formed of steel plates, $\frac{5}{16}$-in. thick, stiffened by channels and tee bars, with floors at intervals. The second floor is the weighing room and the third floor contains the tipping gear and dust seals. The water-tight flat on top supports the receiver filters and framing for handling pipes. The control cabin extends outwards in front of the structure, and allows the operator a full view of the deck of the vessel and quay. The cabin contains the winch for derricking the booms and controller for travelling and jacking.

Travelling Gear.—The structure is mounted on four compensating bogies, each with two cast-steel ground wheels, 2 ft. 6 in. diameter. These wheels are driven through steel gearing with machine cut teeth by a 30 b.h.p. series wound motor which is fitted with a solenoid brake.

Cross Traverse.—The cross traverse motion is obtained by jacking up the structure to a height of 3 in. above the rails, the bogies are then turned through an angle of 90 deg.; after which the structure is lowered on to the rails and, by the same gearing as used for longitudinal travel, is traversed into a recess. The process is repeated when the elevator requires to be placed on longitudinal rails, and the time taken for the complete operation occupies about fifteen minutes.

Jacking Gear.—To lift and lower the elevator, the total weight of which is 110 tons, screw jacks are provided, one at each corner. The screws are 4 in. in diameter, $\frac{3}{4}$ in. pitch, and work in gunmetal nuts which

MODERN DOCK APPLIANCES AT GLASGOW.

Fig. 5. SPEED-INCREASING GEAR. SCALE 1/10TH.

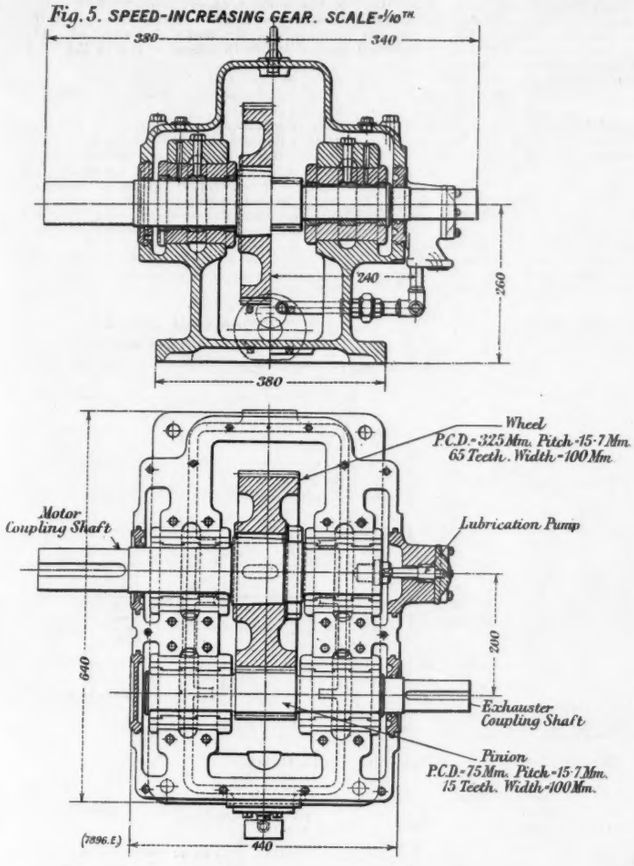


Fig. 6. EXHAUSTER SPEED-CONTROL. PNEUMATIC GRAIN ELEVATOR.

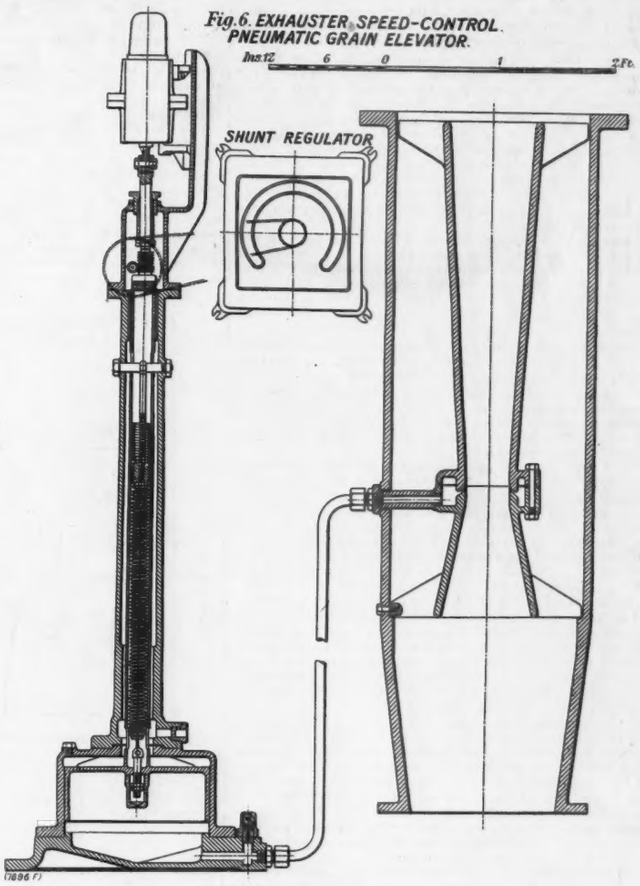


Fig. 7. RECORD OF VACUUM, MOTOR CURRENT, SPEED AND QUANTITY WHILE OPERATING BULK GRAIN.

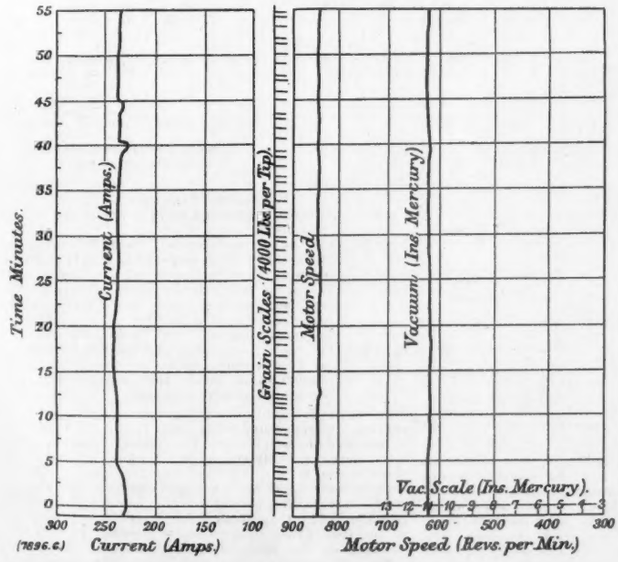
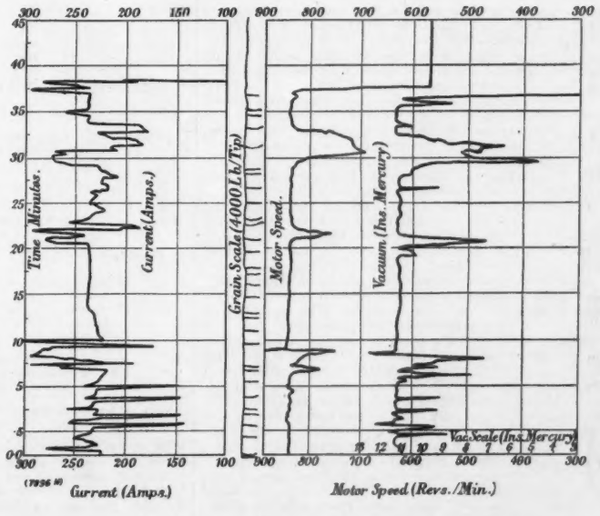


Fig. 8 RECORD WHILE CLEANING-UP HOLD.



are encased in heavy cast-steel brackets. Steel gearing and shafts connect the screws to a 10 b.h.p. motor placed on the first floor.

Intake Pipes.—Two booms of weldless steel tubing, each 12 in. diameter of bore, are connected at inner ends to ball-and-socket swivel joints. The outer ends are fitted with rectangular bends and have renewable wearing plates where required. Telescopic pipes, 9 in. diameter of bore tapering to 7 in. diameter, are provided, and combined with the power luffing motion of booms give a vertical movement of 25 ft. when working in ships' hatchways. The winch for operating pipes and boom is placed in the control cabin, and consists of four barrels operated through worm-gearing by a motor of 5 b.h.p. The worms are controlled by special friction clutches which in the "off" position apply a braking effect and prevent the load overhauling the worm.

Receiver and Discharging Mechanism.—The receiver is cylindrical in form, 10 ft. 8½ in. in height with a diameter of 6 ft. 3 in., and is fitted with cyclone dust collector; the bottom is coned for free delivery of the grain.

Filters.—Duplicate filters are fitted on top of the structure for the purpose of extracting the dust carried over from the receivers. The air is drawn through fabric sleeves, and the dust which collects is dislodged by mechanically operated shaking gear and discharged through rotary seals and worm conveyors into the top hopper of the weighing machine. A motor of

5 b.h.p. is provided for operating the grain and dust discharging mechanism.

Tipper Discharger.—The grain is discharged from the bottom of the receiver by an oscillating tipper, motor operated, fitted with automatic closing gear and protected against damage from any solid matter being jammed between tipping box and seating.

Grain Scales.—This apparatus consists of an Avery automatic weighing machine, having a capacity of 4,000 lb. of oats per tip and a residue weigher of the steelyard type; a motor for jacking up the weights is also provided. The top and bottom hoppers are constructed of steel plates with access doors for cleaning and adjustment of the weighing machine mechanism. A telescopic shoot is provided on the bottom hopper for delivery of the grain to the subway bands, and a shoot with control valve is fitted for feeding the grain to the portable conveyor bands for delivering the grain into the transit sheds.

Supply of Electrical Energy.—Direct current at 500 volts is taken from plug boxes at quay level, which are fed from a ring main erected in the subway. The current is supplied by the Glasgow Corporation Electricity Department on a kilowatt basis of maximum demand which has worked out on an average cost for the past year of 1·16*d.* per unit.

Lighting and Heating.—The internal lighting consists of incandescent lamps, and two arc lamps are provided in front of the structure for illuminating the deck of vessels while being discharged; plug fittings are also provided for supplying lighting in holds. The heating is by resistances enclosed in tubing which take the full voltage. This method has proved satisfactory and obviates any risk of fire.

Exhauster.—This was designed and made by Messrs. Reavell and Co., Limited, Ipswich, of the three-stage rotary type in one unit, and together with the driving motor and speed-increasing gear is mounted on a common bedplate of deep section.

The exhauster is designed for a nominal vacuum of 10-in. Hg. and an aspired volume of 5,200 cub. ft. per minute with speed range of from 2,800 r.p.m. to 3,580 r.p.m.; the highest vacuum obtainable being about 11½ in. The casing is built up in sections. The rotor-shaft revolves in two roller bearings, and the axial thrust is taken by a special ball-location bearing. The driving motor is of the direct-current shunt-wound variable-speed type, having a maximum output of 183 b.h.p., and the speed can be varied from 650 r.p.m. to 810 r.p.m. Flexible couplings of the pin and rubber bush type are fitted on the motor and exhauster shafts.

The speed-increasing gear (Fig. 5, on preceding page) is of the "Maag" type, with a ratio of 1 to 4·33; the spur wheel on the motor shaft being 32·5 mm. pitch diameter by 100 mm. broad, pinion on exhauster spindle 75 mm. pitch diameter, and the pitch of teeth 15·7 mm. The gear-case is of cast-iron having bearings lined with white metal, and a plunger pump operated from the low-speed shaft is provided for supplying a spray of oil to the gear wheels and lubricating the shaft bearings, also the roller and ball bearings, of the exhauster.

The temperature of the bearings, which in the case of that at the discharge end of the exhauster, rises to 160 deg. F., and entails the oil being cooled. As water is not available, a tubular cooler is provided, air being drawn through thin brass tubes by a fan operated from the exhauster shaft. To enable the exhauster to be started and stopped by the operator in the control cabin, an automatic contactor panel with time relay is provided and placed alongside the main switchboard on first floor.

Speed Control.—For the purpose of controlling the output of the exhauster at low vacuum, which occurs when the nozzles are operating in thin layers or when they are withdrawn from the grain, a system has been installed which, in actual service, gives every satisfaction. This arrangement is shown by Fig. 6, and consist of a Venturi pipe placed in the air-delivery pipe of exhauster, the throat of which is connected to a piston which is suspended by a tension spring. A spindle is carried up from the piston and engages with a rack and chain wheels which operate the shunt regulator.

A solenoid is fitted to the gear and interlocked with the contactor panel, its function being to retain the shunt regulator in the starting position until all resistance in the circuit is cut out and the motor has reached its minimum working speed. The solenoid is then automatically cut out and the shunt regulator immediately takes up a position corresponding to the amount of air passing through the exhauster at that time. Any variation in the volume of air passing through the exhauster produces a corresponding variation of the static pressure in the throat of the Venturi pipe. This variable air pressure is transmitted to the underside of the piston; atmospheric pressure acting on the top side of the piston and the pressure in throat being negative the tendency is to pull the control piston downwards and move the shunt regulator against the action of the governor spring which can be regulated to alter the speed of motor and volume of air which may be discharged.

Charts have been taken during the discharge of bulk grain, Fig. 7, being a record of the vacuum, speed of exhauster, amperes in motor circuit and number of tips of weighing machine during the period the nozzles were sinking. Fig. 8 is a record of similar items obtained when the plant was engaged in cleaning up a hold and indicates the variations in vacuum, speed of exhauster motor and the current taken by same.

From data obtained when the elevator was employed in discharge of wheat in bulk, the curves as shown by Fig. 9 were compiled. A on diagram indicates the conditions when 5,200 cub. ft. of aspired air at about 11½ in. of vacuum is passing through the exhauster per minute. When the volume increases to 5,700 cub. ft. the control piston takes up it slowest position and the motors their minimum speed, this point is indicated by B.

Should the volume increase beyond this value, the performance of the exhauster follows the minimum speed characteristic right down to zero vacuum, point C, at which point the aspired volume reaches a value of 6,700 cub. ft. per minute. Point D indicates the minimum volume of 4,200 cub. ft. below which surging occurs.

The variation in horse-power corresponding to the performance line D A B C, is shown by curve E F G H, from which it will be seen that the output of the motor at the exhauster coupling reaches a maximum value of 153 b.h.p. at point F, and a minimum value of 112 b.h.p. at point G.

The effect of the automatic control gear is to keep the volume nearly constant over the working range with the vacuum varying from 6 in. to 3 in. to 11 in. to 5 in. with a *pro rata* demand on electrical energy. If the control gear was not employed, the exhauster would run at maximum speed, and in the event of the nozzles being withdrawn from the grain for any lengthy period, the vacuum would fall to zero, in which case the volume would increase to about 9,200 cub. ft. (point I), and the horse-power would reach a value of about 235 (point K), under which conditions the motor would be overloaded and energy wasted. The exhauster has given satisfaction under working conditions, there being an entire absence of vibration, also the speed-increasing gear shows no sign of wear and runs practically noiseless.

Fig. 9. PERFORMANCE DIAGRAM WITH VACUUM REGULATOR.

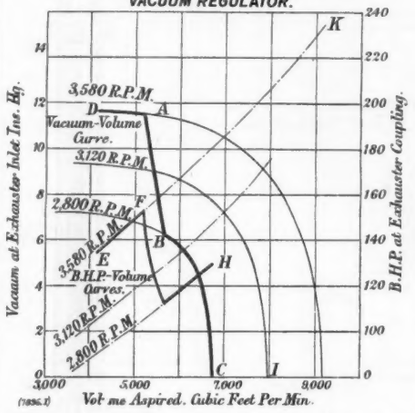
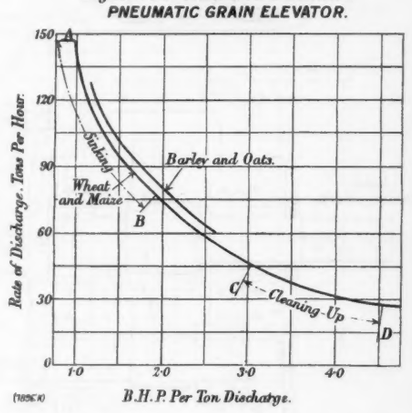


Fig. 10. PERFORMANCE DIAGRAM. PNEUMATIC GRAIN ELEVATOR.



Performance in Actual Working.—Fig. 10 is a diagram showing the rate of bulk grain discharged per hour and the equivalent horse-power used, compiled from hourly readings during discharge of a number of vessels. From points A to B the curves represent the performance while the nozzles are sinking in the grain, and from C to D while the holds are being cleaned up.

Table V is a list of vessels loaded with bulk grain, and gives details of the unloading of the same by the plant.

Cost of Discharging Grain by Pneumatic as Compared with Bucket Elevators.—The two bucket elevators on the quay at Meadowside previously referred to which operate discharging vessels in conjunction with the pneumatic elevator, afford an opportunity of arriving at a comparison of the actual charges incurred by each system in discharging bulk grain from ships and delivering the same at quay level. The particulars set out in Table VI were computed from final reading after the complete discharge of 1,315 tons of North American flat maized from the S.S. Stanmore, both elevators working under practically the same conditions as to the stowage of the cargo and the nature of the material discharged. The following remarks qualify the items of cost in Table VI.

BUCKET ELEVATOR.

Item A.—675 tons discharged in 9 hours at the rate of 75 tons per hour.

Item B.—Electric energy measured by watt-hour meter = 291 B.O.T. units at 1·16*d.* per unit, includes current taken by auxiliary elevators.

Item C.—Wages of two attendants on structure, one weigher, one rigger, part time of foreman and gang of 24 men in hold.

Item D.—Made up from the average annual outlays incurred for repairs and stores during the past six years.

Item E.—The capital cost is taken at 10,000*l.* with interest at 4½ per cent. on an annual discharge of 48,000 tons.

TABLE V.—DETAILS OF UNLOADING BULK GRAIN.

Name of Ship.	Nature of Grain.	Tons Discharged.	Net Time. hr. min.	Tons per Hour.	Total B.O.T. Units.	B.H.P. per Ton.	Maximum Tons Discharged per Hour.	Length of Pipe Line.	Remarks.
Salacia	Wheat	600	5 23	111½	—	—	114	75 to 85	Pipes sinking in bulk.
Salacia	Wheat	704	8 12	85½	—	—	—	85 to 105	Trimming with pipes on bottom.
Graciana	Wheat	188	1 45	107½	210	1·31	—	85	Pipes sinking in bulk.
Hoxie	Wheat	636	8 25	75½	—	—	—	95 to 105	Trimming and sweeping up of holds.
Vitellia	Wheat	746	8 12	91	—	—	—	95 to 105	Pipes sinking in bulk for about 2 hours.
Vitellia	Wheat	184	1 37	113½	199	1·29	—	95	Pipes sinking in bulk.
Bellglade	Maize	864	8 13	104	—	—	—	75 to 85	Pipes sinking in bulk and on bottom of hold.
Nora Saliari ..	Maize	850	7 24	115	907	1·26	125	75 to 85	Pipes sinking in bulk.
Graciana	Maize	224	2 0	112	258	1·32	—	85	Working in bulk for 1½ hours.
Graciana	Maize	426	4 52	87½	638	1·71	—	95	Trimming with pipes on bottom of hold.
Invermore	Barley	205	2 10	94	—	—	—	75 to 85	Trimming with pipes on bottom of hold.
Tarankia	Oats	368	4 31	79¾	—	—	—	85 to 95	Pipes sinking in bulk.
Hoxie	Rye	105	1 40	63	—	—	—	95 to 105	Small parcel.

TABLE VI.

Item.	Details of Costs.	Bucket Elevator. Cost per ton. pence.	Pneumatic Elevator. Cost per ton. pence.
A.	Bucket elevator. B.O.T. units per ton = 0·43	—	—
	Pneumatic elevator. B.O.T. units per ton = 1·6		—
B.	Electrical energy	0·50	1·92
C.	Wages	6·21	1·85
D.	Maintenance and Stores ..	1·25	1·25
E.	Interest on capital	2·25	5·06
	Pence per ton discharged ..	10·21	10·08

NOTE.—Depreciation and general management charges are not included.

PNEUMATIC ELEVATOR.

Item A.—640 tons discharged in 7½ hours at the rate of 85 tons per hour.

Item B.—Electric energy measured by watt-hour meter = 1,060 B.O.T. units at 1·16*d.* per unit; includes current taken by tipper and winch motors.

Item C.—Wages of two attendants on structure, one weigher, one rigger, part time of foreman and gang of six men in hold.

Item D.—Taken as being similar to bucket elevator.

Item E.—The capital cost taken at 30,000*l.* with interest at 4½ per cent. on an annual discharge of 64,000 tons, being the proportion of the estimated annual discharge.

From the foregoing it will be observed that the cost per ton in discharging bulk grain is slightly in favour of the pneumatic elevator, but under conditions of a larger cargo, suitably stowed, the bucket elevator would show better results, by reason of the greater bulk of cargo which could be discharged without trimming.

The advantages gained by the introduction of the pneumatic plant at Meadowside have been principally in the time saved in discharging parcels of grain and cleaning up the holds after the bucket elevators had taken out the greater part of the cargo. In dealing with part cargoes in twin-screw vessels with tunnels in after-holds, and in ordinary cargo steamers with grain stowed in deep tanks, the pneumatic plant has greatly accelerated the rate of discharge. In some instances three days of the ship's time have been saved. Without this plant, many cargoes could not have been dealt with at the granary, and would have been unloaded into the transit sheds by portable elevators at greater cost, besides occupying valuable space required for general cargo.

(To be continued.)